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Characteristics of technology development

– A comparative case study of four companies operating within the oil and gas industry

MSc in Innovation and Entrepreneurship

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Abstract:

By studying how firms facilitate for, and organise technology development, the underlying characteristics of technology development may be analysed. How a firm evolves depends on how past events impact on a firm's knowledge base, routines, network and technological trajectory. Perhaps the most common way of innovating is through recombining existing knowledge and building upon an existing fundament.

This thesis analyses and compares four small to medium sized companies operating in the oil and gas industry. The empiric data has been gathered through qualitative interviews. By identifying the characteristics of technology development, and comparing how firms develop technology, allows for an operationalization of the concept of organisational path dependence. It also opens up for a more analytic view on the evolutionary perspective of firms.

Keywords for the library: Technology development, organisational path dependence, knowledge bases, routines, networks, technology trajectory, innovation, small to medium sized enterprises

Preface

This thesis marks the finish of a two-year Master of Science in Innovation and Entrepreneurship offered by Bergen University College and the University of Oslo. Through my studies these two years I have acquired a foundation of knowledge and experience to better pursue a professional career. Coming with a background in physics and to start thinking like a businessperson has been an interesting learning curve.

I would like to use this opportunity to express my gratitude towards my supervisor and professor Stig-Erik Jakobsen. His supervision has provided encouragement and insightful guidance on how to structure my thesis. It has been an educational and inspiring process.

I would further like to thank the firms, APIteq, Epsis, Scantrol and Stormfjord for their willingness to participate in my research, and their valuable contribution during the interviews.

Lastly, I will give my thanks to my mother for taking the time to check my grammar and sentence structure.

Abbreviations

AHC	Active Heave Compensation
CCI	Complex Combined Innovation
DUI	Doing, Using, Interacting
IMR	Institute of Marine Research
NCE	Norwegian Centre of Expertise
NFR	Research Council of Norway
OTC	Offshore Technology Conference
PIC	Projects, Infrastructure, Communication
R&D	Research and Development
STI	Sience, Technology, Innovation
VAM	Visual Asset Management

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1. Introduction

Technology development and innovativeness are generally not linear processes. Not before there is an existence of, or exists, a commercial need, will firms tend to be interested in innovating. A firm will normally start exploiting the market opportunity by reviewing and combining existing knowledge. Should this reliance on existing knowledge fail, a firm may invest in more basic research. The progression to produce a new technological innovation typically goes through a myriad of loops and feedback rounds. The resulting technology may even be completely different from initially intended (Fagerberg 2005, p. 8-9).

Firms, or organisations, are not passive bystanders, they have the ability to influence, affect and form their environment. Strategic technology development is dependent on an active management, well-established routines, organisational learning, and also the ability to adapt to change (Lam 2005, p. 133). Over time firms develop their own way of doing things, or they create their own organisational path. Both evolution and history of technology development consists of a combination of random factors and more systematic elements. Encapsulated by firms, technology development is characterised and driven forth by chance and necessity (Verspagen 2005, p. 496-497). Technologies, undergoing rapid changes in industries driven by an engineering workforce, often require close interaction between the users and producers of technology. In other words, actively using a network for acquiring technological impulses is very important for small firms, and doing innovative activity through partnerships may even be a way of substituting or complementing a firm's internal capacity for technology development (Narula and Zanfei 2005, p. 333-335).

Doing research and development requires a substantial amount of resources, which smaller firms often do not have access to. However, smaller enterprises lack complex formal internal structures, and may be quicker to innovate. In order to promote technology development, smaller firms often receive grants from governmental technology institutions (Tunzelmann and Acha 2005, p. 420).

Technology development can be viewed as *"a process of learning and knowledge creation"* (Lam 2005, p. 124). The ability to innovate has a root in the cognitive

foundation of firms, and its capacity to develop new knowledge for solving problems. Over time, as a firm evolves its organisational path, a firm also cultivates a collective organisational knowledge, which may be greater than the components of knowledge the individuals in a firm possess. The mixture of knowledge will characterise how a firm might be organised to develop new technology.

Going back to the evolutionary perspective of how firms innovate, most firms will over time experience path dependency. Path dependency is brought on by self-reinforcing mechanisms, like when a firm doing continuous improvements within one technological trajectory, until diverging from a path becomes too expensive to conduct. As path dependency can make a firm and its technology more unique. Being path dependent may, until a certain point, be beneficial for a firm (Fagerberg 2005, p. 10). In addition to improve upon existing knowledge, routines and technology, a firm should seek external dialogues with partners, customers, research facilities etc. Doing so will enable firms to seize coming opportunities and to keep a firm's path more open-ended.

The degree of path dependency may also vary, depending on how a firm chooses to extend, renew or recreate its path. The factors affecting technology development appears to be the different features of a firm. However, how exactly do knowledge, routines, network and technological trajectories shape how firms innovate and develop technology? This is what I aim to pursue and illuminate in my master thesis.

1.1 Research questions and perspective

The purpose of my thesis is to specify and analyse how technology development is organised and executed in small firms in the oil and gas industry. Hence, the main research question is:

> *What are the characteristics of technology development in small firms operating in the oil and gas industry?*

To characterise the technological development in firms, I will be considering firms' degree of path dependency, knowledge foundation, routines, technological trajectories and networks. Based on the theoretical framework surrounding these concepts, my

assumption is that technology development is strongly connected to the evolution of firms, and how firms continue to build upon the fundament, which they have acquired at the time of founding. This is the organisational path dependency of the firms. I further seek to determine the common factors for technology development in small firms that are considered to be innovative. The additional sub-research questions are:

What role does path dependency play in technology development?

What are the similarities and differences of technology development in the selected firms?

Chapter two will present the theoretical grounds for discussing the research questions. Chapter three will describe the method I have used to conduct the necessary empiric research, and chapter four will use the theoretical framework to illuminate the research questions through an analysis and comparison of four small firms (APIteq, Epsis, Scantrol and Stormfjord) which operate in the oil and gas industry. Lastly, chapter five will go through the main findings of the analysis, connect the research questions with my findings from the analysis, and offer up points for further study.

2. Theoretical framework

The present chapter will go through relevant theory for illuminating the research questions. The section will start off with an evolutionary perspective of how technologies and firms develop. Building upon the evolutionary foundation, the chapter will further look at how firms tend to evolve along a specific path and become dependent upon their previous actions. It will finally be shown how the development of technology is connected to all aspects of an organisation: the history, the knowledge, the technology trajectories, the routines and the networks. This listing comprises the main components for how I will characterise technology development.

2.1 Evolutionary perspective

What is meant by the term innovation? On the most basic level innovation is the result of a process where an idea is applied and developed into a viable method/process or product (Fagerberg 2005, p. 4-5). Innovation is a continuous process, which may

complicate quantifying the degree to which innovation occurs. Ever since Schumpeter published his great work in the first half of the 20th century (Fagerberg 2005, p. 6), and until present day, a significant amount of research has been catered towards finding one or more methods for successful innovation, knowledge- and process development. Schumpeter defined innovation as "new combinations" of existing resources, which in turn were carried out by entrepreneurs.

Innovation may be defined for two different contexts, on the organisational level and on the technological level.

Ever since Torstein Veblen in 1898 posed the question about why economics is not an evolutionary science, the study of economics, innovation, technology development and path dependence has gradually gotten an added dimension; the evolutionary perspective (Martin and Sunley 2006). This perspective has strong ties to the idea of path dependence (this last concept will be explored in greater detailed later on). A multitude of evolutionary patterns can emerge from a single initial path. Path dependence relies heavily on what has come before in history, and should a path reach the state of lock-in (this concept will be explored in greater detail later on), this does not necessarily mark the end of a system. Evolution may happen through gradual change of a system by continuously adding new or different rules and procedures, through rearrangement of existing roles and tasks, or more radically through recombining by using the existing framework to build a new one (Jakobsen, Byrkjeland et al. 2012).

A related concept is that of co-evolution. It prescribes that routines and industrial economic activities go through a mutual development process. Co-evolution may also be applied when considering several systems, i.e. a mutual and parallel development of structure, knowledge and technology. Just as with evolution, co-evolution often displays the characteristics of path dependence. The systems involved in such processes are often complementary and dependent on each other (Karlsen and Isaksen 2008, p. 44).

As this thesis centres on the characteristics of technology development, evolutionary paths and the surrounding factors, technology as a concept needs to be defined.

According to Jones (2013, p. 262) technology is defined as "*the combination of skills, knowledge, abilities, techniques, materials, machines, computers, tools, and other equipment that people use to convert or change raw materials, problems and new ideas into valuable goods and services*". Within an organisation, technology can exist on several levels, whether it may be individual (skills and knowledge of each person), functional or departmental (the collective effort of individuals can create competences that constitute technology) or organisational (the conversion of inputs to outputs can define technology at the organisational level).

In research and development (R&D) and in the process of developing new products, the accumulation of knowledge is a key component. These two processes often go together. SSB chooses to define R&D as creative work undertaken systematically to increase knowledge, and also include use of this knowledge to devise new utilisations (SSB 2013). In fact, the development process that any innovation or technology goes through can be divided into three stages. This will provide a simplified picture of the process, and the stages are as follows: The idea phase, the development phase and the commercialisation phase (Trott 2012, p. 328). There are of course a multitude of other factors that may also contribute to this process; these may be internal and external factors of an organisation, and how the organisation works to develop technologies or innovations.

Figure 1 The stages an innovation passes through, based on Trott (2012)

2.2 Path dependence in organisations

The evolution and development of organisations characterises the path an organisation will follow. Embedded in this lies how the organisation works, the importance of historic events and how their technological scope may narrow or broaden. The formation of organisations affects their ability to develop technology, do research and how to introduce technological innovations. As a result there will be some ways of forming an organisation that may promote and advance innovation of new technology, while other instances may hold an organisation back.

Path dependence is a concept that was briefly mentioned earlier on in section 2.1, but what is it exactly? It is often associated with static organisations, inflexibility, and general inability to change ones existing path. As a broad term within organisation research, path dependence entails "*all kinds of imprinting effects of the past on organisational behaviour*". (Sydow, Schreyögg et al. 2009) This basically says that what has already been done, influence current and future decision-making. However, giving such great weight to history makes for a very open understanding of path dependence. In a more narrow term, path dependence concerns features such as sustained persistency and potential lock-in. These situations are perhaps not the contemporary focus point of the decision makers. How then does organisational path dependency come into existence?

Sydow, Schreyögg et al. (2009) postulated three stages to the development of path dependency. First off is singular historical events, then follows that these events may undergo self-reinforcing dynamic mechanisms, and lastly there exist the possibility of organisational lock-in. As an organisation's path is formed it becomes more and more predictable, thus loosing its flexibility and becoming more rigid. This in turn can at a later stage remove more efficient options for the organisation, as the organisation's previous choices have caused a lock-in. The three stages of path dependence will hereafter be referred to as the preformation phase (phase I), the formation phase (phase II) and the lock-in phase (phase III).

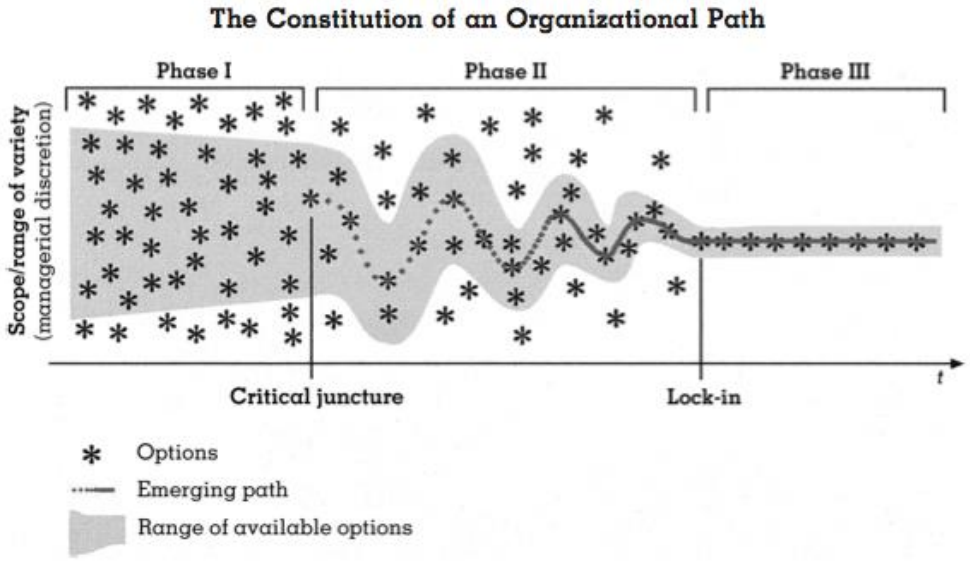

Figure 2 Organisational path ***(Sydow, Schreyögg et al. 2009, p. 692)***

The preformation phase tends to be an open situation with hardly any restrictions regarding scope of action. Here the organisation is figuring out what direction to take, and how to orient itself towards finding the optimal path for success and meeting the coming innovation challenge. However, even at this stage, the development of a path is present. Here too, other factors and developments can be an influence and put its mark on how the organisation is to develop. A significant part of this may be linked to the organisations routines and their imprint. It should be noted that this first phase does not equalize a determined state from the start, also initial choices do have an impact (Sydow, Schreyögg et al. 2009).

Initial choices may seem innocent, but they may also work as trigger-events for developing a path, choices are impetus. The initial choices trigger more choices and actions, which all together form an organisational path. Are these events characterised by randomness? No, the initial choices have motivations and intentions lying behind them. In fact, path dependence may even be the result of conscious strategies. A main point of early path developments to emphasise is that the path is contingent in character (Sydow, Schreyögg et al. 2009).

The formation phase is marked by the organisation evolving towards one path, and this path will gradually emerge as self-reinforcing processes take place. Further, this

phase is a result of a choice or action that triggered a critical juncture for the further development of the organisation. It should be noted that not all situations with competing solutions lead to path dependence (Sydow, Schreyögg et al. 2009). How organisations develop will impact their path dependency, and some organisational formations may be better suited for fostering innovation.

The self-reinforcing processes are in research often connected to the decisions of individuals, while it may be more beneficial to study the entire organisational context that form up the basis for decisions. Other factors that may cause or enhance the self-reinforcing processes may be emotional reactions, cognitive biases or political biases. The formation phase still has elements of contingency (Sydow, Schreyögg et al. 2009).

The last part of this tripartite is the *lock-in* phase, which is characterised by a continued restriction of scope. In the most extreme form this phase assumes a deterministic character, with high transaction costs and decisions that are bound to replicate the path. Organisational paths however tend to be more ambiguous and complex in their nature. In organisations the self-reinforcing mechanisms are often deeply integrated within the organisations routines and preferred way of action. These characteristics of organisations are consequently difficult to break (Sydow, Schreyögg et al. 2009).

For an organisation experiencing lock-in, there is still space for variations along the path, and how one goes about moving further down the path. The eventual lock-in is a result of past decisions and positive feedback along the way. The danger of being locked-in is in becoming inefficient in comparison to alternative organisations and technologies. The inefficiency culminates from being unable to adapt to better alternatives or changes in internal or external situations that require different solutions (Sydow, Schreyögg et al. 2009).

Lock-in is often associated with negative connotations, which is described as a path that has lived past its time and become inefficient in some manner. However, it may be argued that there exists a duality to lock-in processes. The initial lock-in may be positive for an organisation or technology and contribute to reinforce the local

industrial dynamism through processes of learning and specialisation. As time passes, this positive state may transform into a negative lock-in, where the mechanisms that previously performed as success factors, now become a source of inflexibility and inefficiency (Martin and Sunley 2006).

While Martin and Sunley here describe lock-in at a regional and industrial level, I consider the same concept to be applicable and similar at an organisational level. The lock-in can thus be an advantage fostering learning and the development of specific competence, which again can stimulate the innovativeness of the organisation, while as time passes it might narrow performance and hinder innovation.

Positive and negative lock-ins are the two extremity points on a continuous spectrum. A positive lock-in represents an organisation whose formation and specialisation advances innovation. A negative lock-in is consequently the opposite situation. Lock-in is the extreme form of path dependence, and path dependence may also occur to different degrees. As such it is often common to differ between a weak, a moderate and a strong form of path dependency. Liebowitz and Margolis (1995) considered the impact of these three types of path dependence to be progressively stronger. The first degree of path dependence, the weak form, is merely an affirmation that there is a connection between past, present and future events. The second degree of path dependence implies intertemporal effects may generate errors or a negative form of path dependence (i.e. negative lock-in). Lastly the strongest and third degree of path dependence also says that intertemporal effect will cause error, but also that the error could have been avoided. So, the development of path dependence is not a rigid scheme always leading to a strong form of lock-in. There are a myriad of variations and incidents along the way that may alter or strengthen path dependence.

Discovery and creation theory

From where do the opportunities that may become innovations originate? According to Alvarez and Barney (2007) opportunities can either be discovered or created, however both scenarios are concerned with entrepreneurial action and the human aspect. Taking a step back, discovery theory assumes every opportunity to already "be there" just waiting for an entrepreneur to pass by and seize it. Creation theory, however, assumes there are no opportunities that exist independently of

entrepreneurs, i.e. they must all be created. This makes the decision chain more inductive and uncertain for the entrepreneurs; while in opposition discovery theory consist of risky calculated decisions.

In discovery theory a known and well-defined opportunity gives way for a more predictable and stable environment, where one may more easily calculate what resources needs to be acquired for achieving ones goal. Changes in the marketing mix may be how new opportunities manifest themselves. However, in creation theory, the path forward is emergent and changing, and it is thus not necessarily known what will be needed to achieve ones goal. In fact, the marketing mix may change fundamentally as a result of new opportunities that emerge (Alvarez and Barney 2007).

Schumpeter viewed (in particular large) companies as the innovators, and also considered these companies to be engaged in the process of "creative destruction". Creative destruction is based on new technological innovations or products destroying the existing technologies or products, which were the innovations of the past. This is a cyclic and continuous process, and is closely entwined with technological and organisational innovations (Lazonick 2005).

Discovery and creation theory shows the importance of the entrepreneur within evolutionary thinking, who might be at the centre point for how an organisation's path develops. The entrepreneur can be an initiator for promoting change. Having a complete focus on path dependency may come off as being rather deterministic. However, viewing opportunities as an aspect to be created or discovered by an entrepreneur, add another dimension to how technologies and organisations may develop.

Path dependence and evolution

In the beginning of this theory section a relation between path dependence and evolution was mentioned. Does path dependence foster evolution or is it the other way round? Existing theory regarding path dependence reveal little about how new paths come into being. It is clear how, once selected, a path forms through self-reinforcing mechanisms, however it is less clear why one novelty is chosen instead of another. Path dependence can here be seen as results of initial evolutionary

mechanisms, e.g. selection and adaptive learning. Martin and Sunley (2006) wrote that "*All evolutionary processes and mechanisms could be argued to be path dependent; but not all path-dependent processes need be evolutionary."* This says that for a path dependent system or organisation to be evolutionary it needs mechanisms that generate innovation. These mechanisms will lay the foundation work for new paths to develop. This in turn implies that a path stuck in a negative lock-in has lost its evolutionary properties.

Organisational paths and path dependence evolve over time through processes of continuation and change. What may be interesting is how organisations cope with change, whether they remain in stasis or obtain the ability to alter their way of operating. Some organisations and companies are well adapted to thinking 'outside the box' and handling unforeseen events, while others struggle. It is generally very difficult to break with habits and routines, and to do so requires competence and knowledge to meet the challenges ahead. The knowledge foundation becomes an integral part in the formation and development of an organisation.

In the literature organisational path dependency may appear to be a rather unclear and vaguely defined concept. Therefore, to operationalize organisational path dependence I will in the further discussion focus on:

- Organisations' knowledge
- Organisations' routines
- Organisations' technological trajectories
- Organisations' network

2.3 The knowledge and routines of organisations

Organisations have a multitude of different traits, one important trait is the knowledge possessed by the employees, and perhaps even more important is the collective knowledge of an organisation. Knowledge and generation of new knowledge may be considered core building blocks for advancing technological development. The use of an organisation's knowledge is enveloped in the organisation's routines.

Organisational knowledge

The rate of development of knowledge and technology may be high if unlimited access to resources are poured into a project, however this is seldom the case. The ordinary progression level for a new technology is a slow start, followed by a more rapid increase, and then the curve levels off as the current physical limits of a technology has been reached (Trott 2012, p. 203). Even as technologies are created and eventually left behind, some organisations manage to prevail through the shifting tides of technology development. These organisations have to constantly manage to remain innovative and effective. What is it these organisations know or do to grant them longevity and success?

Individuals within an organisation do not possess the combined knowledge of the entire organisation, but an organisation as a whole can contain and retain that knowledge. This is a collective form of knowledge, and it is more than the simple sum of each employee's knowledge. This organisational knowledge lies within the operations and expertise of an organisation, and is thus the distinct heritage of each company. This heritage is acquired through individual application of technology, and represents a tacit dimension of organisations. Internal systems, routines, shared understanding and practices represent this dimension. There is one other factor that may also contribute to the way that organisational knowledge functions: that is knowledge embedded in relationships between individuals of an organisation. This serves two purposes: it combines the individuals' knowledge bases and makes knowledge sharing easier within the organisation (Trott 2012, p. 204-207).

Tacit and codified knowledge

To turn an invention into an innovation, there may be a lot of different processes to coordinate. Innovative environments may grow up around different kinds of knowledge, which are often categorized into codified and tacit knowledge. Both are concepts for how knowledge may be transferred and shared. In 1967 Polanyi wrote in The Tacit Dimension that the starting point is: "*we can know more than we can tell*" (referred in Smith 2003). This quote is descriptive for the concept that Polanyi called tacit knowledge, and comprises knowledge as a thing, a product or action, which results in knowledge. This type of knowledge is communicated via actions, i.e. not verbally. Further, seeing as it is action-based, it will in reality function as a

combination of empirical and theoretical knowledge. The tacit knowledge will thus always be linked to the context that it is presented in, as well as linked to an individual's or group's perception and understanding (Karlsen 2008). On the other hand, the codified or explicit knowledge is more heavily weighted towards the theoretical, and is characterized by the fact that it may be written down and without complications transferred verbally. Tacit and explicit knowledge are polar opposites regarding transfer costs. Tacit knowledge is most easily exchanged on a local level, while explicit knowledge may just as easily be shared on a global level (Bathelt 2004). The most profitable way to transfer knowledge is often a combination of these two types, as they individually will either be too costly (tacit) or not valuable enough (codified) (Powell and Grodal 2005, p. 75-77). According to Bathelt (2004) knowledge may in and of itself be considered as a source for further generation of knowledge.

Knowledge bases

The term knowledge base refers to the main type of knowledge necessary for the development of new knowledge and for innovative processes to take place. A different way of considering knowledge base is as the type of knowledge dominant within firms in an industry. Asheim and Isaksen (2008) describe a trichotomy of knowledge bases, where the categories are as follows: analytic (research based), synthetic (experience based) and symbolic (art based).

In an industrial setting where innovation is the result of existing knowledge being combined or applied in new ways, a *synthetic knowledge base* will often be prominent. Here an innovation is often the outcome of a perceived need or problem arisen trough dealings with their peers. Innovations derived from such situations are generally based on applied research, and research and development (R&D) is consequently considered less important. Experience and "know-how" are the drive of the synthetic knowledge base. Engineers' fits, as an example, generally nicely into this category. This is thus an interactive knowledge type, where much is tacit knowledge, but with some codified elements. The innovation model is based on learning by doing, using and interacting (DUI). The goal for companies and industries with a synthetic knowledge base is to be efficient and deliver reliable solutions to their customers. To diminish risk and uncertainty of the innovation process, the

preferred mode of innovating is to make modifications to existing products and processes. Implicitly, these are processes taking place in existing companies, which may result in lessening the exploit of new synthetic knowledge (Asheim and Gertler 2005, p. 295).

The foundation of an *analytical knowledge base* is scientific knowledge and research. This is knowledge that is based on formal models and is mainly codified, i.e. it can be written down and tested by scientific methods. Even so tacit knowledge is not to be overlooked, as both kinds of knowledge always work together in an innovation process and knowledge creation. Companies with a strong analytical knowledge base tend to operate their own R&D departments, as well as often having close ties to universities and other research institutions. This type of knowledge base is more likely than the synthetic one to generate new products and processes, i.e. radical innovations (Asheim and Gertler 2005, p. 296). The innovation model may seem linear and may be described by the following three words: Science, technology and innovation (STI) (Asheim and Isaksen 2008, p. 30).

The last type of knowledge base as described by Asheim and Isaksen (2008) is the *symbolic knowledge base*. This knowledge type is typical for companies operating within the culture sector. The learning process is largely done through creative processes either by individuals or in teams. The innovation model may here be termed as projects, infrastructure and communication (PIC), or learning by doing. In some ways the companies dominated by this knowledge type resemble the DUI model, but even so they keep a more open innovation structure. The way these companies work is through projects, where they make use of external specialised knowledge and resources. The products and services they develop often have central communication elements (Asheim and Isaksen 2008, p. 27-30).

There is a fourth mode of innovation, which can be seen as a combination of the analytical and synthetic knowledge base. It may be described as complex, combined innovation (CCI). As implied this model combines the use of scientifically based and experience based knowledge from different sources in innovation projects. (Isaksen and Karlsen 2013) Bridging these two knowledge bases is not necessarily easy, as

there may be a lack of compatibility between industrial and R&D knowledge bases (Njøs, Jakobsen et al. 2013).

Analytical knowledge bases are mainly represented in larger urban areas, where close relations and connections to nearby R&D institutions may be maintained. In contrast, smaller regions are better suited for companies with a synthetic knowledge base. However, for all the different knowledge bases, an important aspect is to be able to reach beyond the company's region, and to draw on external knowledge. Continuous knowledge exchange may faster spread innovations and new knowledge, so that an avalanche effect of knowledge generation may occur (Isaksen and Karlsen 2013). Industries continually undergo change, where companies, knowledge and technology are built up over time. This entails an increasing difficulty with regards to changing a company's chosen path, and is referred to as path-dependence. As previously mentioned, a nearly related concept is lock-in which implies that an existing company is sustainable only for as long as the reason for its existence exists (Karlsen and Isaksen 2008, p. 45-46).

Combinations of different knowledge bases may be considered a theoretical ideal for a firm, but in reality there may be a discrepancy between the different knowledge bases, e.g. an analytical and a synthetic knowledge base may not be a compatible mix. A rigid distinction between a few knowledge bases seldom exists in practice, but singling out the differences of knowledge bases may be beneficial when finding bridging solutions. To bridge these knowledge bases require collaboration and trust of the individuals and organisations involved, and it is also desirable to have geographical proximity to work partners, whether they be internal or external partners (Njøs, Jakobsen et al. 2013).

The strict categories of the knowledge bases appear perhaps to be too rigidly set compared to what one may meet and experience in reality. It is likely that a majority of companies and industries rely on buttresses from several disciplines. I therefore propose that the different knowledge bases may to a greater extent overlap within single organisations. A company may employ a mix of people with a technical background, academic background and a creative background. It is how these very different people manage to collaborate and to be innovative and productive that often

defines the success of knowledge. Diversity tends to foster a broader perspective, and it is my impression that a combination of these knowledge bases may produce the most innovative and profitable result.

The analytical, synthetic and symbolic knowledge bases place a great focus on the individual parts of an organisation, their background, experience and preferred mode to work in. Even so, they may form a good basis for characterising the type of skills an organisation possesses and base their work upon. The prospect of an organisational knowledge base has an evolutionary perspective due to the fact that an organisation develops and creates its knowledge base over time. New, different and existing assets are gathered and integrated to make up an organisation, and the individual combinations of these assets may very well be a determining factor for how innovative and successful an organisation manages to be. I consider this to relate closely to organisational path dependence.

Organisational learning

Another concept that goes hand in hand with the organisational knowledge base is that of organisational learning, which tackles how an organisation continually develops and creates knowledge. According to Jones (2013, p. 364) organisational learning is "*the process managers use to improve organization members' capacity to understand and manage the organisation and its environment so they can make decisions that continuously increase organisational effectiveness*". This process is vital for organisations in today's rapidly changing market. An elementary tension in organisational learning, as noted by March in 1991, is balancing the competing goals of "*the exploitation of old certainties*" and "*the exploration of new possibilities*" (Lam 2005, p. 126).

An organisation concerned with learning, designs its structure, culture and strategy purposefully to gain maximal potential learning. Of the two learning types, exploitation and exploration, exploration more specifically involves looking for and trying out new forms of organisational activities and procedures to increase an organisation's effectiveness. Exploitation also seeks to increase effectiveness, however the angle is different, because it involves learning ways to refine and make improvements to existing organisational activities and procedures. An organisation

may learn and encourage learning on different levels; these are individual, group, organisational and inter-organisational (Jones 2013, p. 364-365). Learning on all four levels may be present at the same time. The design of an organisations structure will greatly impact how learning is achieved.

The ability an organisation has to learn, and balance exploitation and exploration is connected to an organisation's degree of path dependence and lock-in. A strong degree of path dependency may entail little learning, and the reverse situation with a weak form of path dependency may better generate organisational learning. I consider the exploration of new possibilities to be a characteristic of a broader and more flexible path, as an outward search for new chances and prospects may add different knowledge and thus increase the capacity for learning. Even so, exploitation is needed to be able to fully develop an organisations path and technology.

Bridging knowledge gaps

An organisation's knowledge can, as mentioned, be made up of different knowledge, whether it is of a synthetic, analytic or symbolic kind. The oil and gas industry is often characterised as having a strong synthetic knowledge base. However, technology development does also often bear an analytical knowledge element. This duality requires the oil and gas companies to communicate and to some degree collaborate with research and development institutions. The two may need to bridge and combine their different knowledge to master the technological challenges they face.

Academics usually term research as the systematic approach for discovering new knowledge, while for industries, research is often more generic and is the use of both old and new knowledge to make products. A definition set forth by Roussel et al. in 1991 defined the R&D concept as: "*R&D is to develop new knowledge and apply scientific or engineering knowledge to connect the knowledge in one field to that in others.*" (Trott 2012, p. 274).

Historically, R&D has been viewed as a linear process, but R&D is an uncertain science, and an interactive process may often prove more valuable and profitable. Most companies assume R&D to be beneficial for them, but investing in R&D is

likely to take a long time before starting to generate profits. Activities that are included in industrial R&D are according to Trott (2012, p. 283): "*discovering and developing new technologies*", "*improving understanding of the technology in existing products*", "*improving and strengthening understanding of technologies used in manufacturing*" and "*understanding research results from universities and other research institutions*". R&D therefore consists of fundamental and basic research, applied research and product development. One other point may be added, technical service, which entails improvements in cost and performance of existing products.

Bridging the knowledge gap between R&D institutions and industry is often not an easy feat, but when combined, the industry partners still tend to be the main users of knowledge, while the research partners tend to be the main producers of knowledge. This sets the ground for a discrepancy between the two parties, as the R&D institutions seek industrial feedback and collaboration, whereas the industry seeks access to knowledge. The expectations of such collaborations are often different for each party, and may provide hindrances towards optimal results for all involved. The industry experiences strict time-constraints, and may feel that nearby R&D institutions may have the potential for relevant knowledge transfer, but lack the time and initiative to do something about it. A different way to view this is that the R&D institutions have a tendency to approach innovation as a linear process, while the industry views the innovation process as more interactive and with a main goal of being able to commercialise the innovations. Being able to communicate between the different entities may therefore pose a challenge. A researcher with an analytical knowledge base often has different ways of thinking and presenting knowledge than organisations with a synthetic knowledge base (Njøs, Jakobsen et al. 2013).

A concept that embodies this knowledge discrepancy between different knowledge types is that of *cognitive distance*. Cognition refers to mental activity and the process of knowledge acquisition and understanding through thought, experience, perception, feelings, categorisation and senses. Cognition is developed through actions. Every person thus develops along a different path and obtains different knowledge sets. This leads to a cognitive distance between people, and this distance will be brought into organisations. Internally organisations handle this gap by having a shared interpretation system, which is based on an understanding of shared perception,

interpretation and evaluation embedded by organisational culture. (Nooteboom, Van Haverbeke et al. 2007) This concept will be explored in greater detail in section 2.5.

As presented, there are many different types of knowledge, and there likely exist other knowledge types that have not been deemed relevant to be covered in this thesis. Either way, some knowledge bases may be more inclined to naturally collaborate, while others have a larger gap to bridge. A certain amount of cognitive distances create room for new impulses, while a too large gap may be insurmountable. However, it seems to me, sharing and combining similar or different knowledge presents and opens up possibilities for new knowledge, new innovations and further technology development.

Routines

An inherent component of any organisation is its routines. Edquist (2005, p. 188) defined routines as one of several dimensions of institutions. Institutions are "*sets of common habits, norms, routines, established practices, rules, or laws that regulate the relations and interactions between individuals, groups, and organisations*" (Edquist referred to routines as institutions). Routines are, just like tacit knowledge, difficult to transfer between organisations, but also vital for an organisation's role as a knowledge generator and innovator.

Nelson and Winter (1982) proposed a definition for the term routine with the general outline that "*all regular and predictable behavioural patterns of firms is routine*". Routine is defined in this way to include technical routines for production, procedures for recruitment, inventory orders, investment strategies, R&D, business strategies and production volume. These routines are characteristics of an organisation, and represent some of its history, i.e. they are heritable and remain with the organisation as it and its technology develop over time. Not all problems that businesses face are routine, and not every aspect of business behaviour is routine, but the term serves adequately for the structure of an evolutionary model. In evolutionary theory routines may be seen as a reflection of a set of practices governing an organisation at a given point in time. The routines are an organisation's genes that pass on through history.

When assembling organisational knowledge and routines, the two may be viewed as the organisations memory. With this viewpoint, organisational knowledge is stored in the routines of activity, and the organisation thus "*remembers by doing*", just as a person remembers skills by exercising them. Routines are not static, they undergo changes as organisations evolve, which may be represented by organisations engaging in various "search" operations where they discover or create and evaluate possible changes in the way they operate (Nelson and Winter 1982).

An organisation's structure is closely interlocked with the routines. Informal rules, regulations and routines are often a characteristic of an organisation with a flat structure. A flat structure may stimulate flexibility, and thus mark an organisation's ability of adapting quickly to change. Should, however, the routines be more formal and rigid, an organisation's structure and behaviour will become more predictable (Jones 2013, p. 132).

Organisational structure and routines change and evolve over time. Young entrepreneurial organisations often have a flat structure, and as an organisation grows and creates its path, a common trend is for the routines to become more formal. I consider the ability an organisation has to handle and potentially break an eventual lock-in situation to be largely dependent on the routines inherent in an organisation. A well-functioning set of routines may then encourage an organisation to effectively exploit and explore possible opportunities.

2.4 Technological trajectories of organisations

Technological development can be accumulative, incremental and path dependent. Technology has always been a main component in society, industry and firm development. To understand how technology evolves and changes, one has to consider the underlying processes and trends (Andersen 1998). There might be singular firms at the helm of technology development. Technological trajectories, knowledge, routines and collaborative network are developed in and between firms.

The development of technological knowledge tends to be firm specific, and can seldom be easily transferred or applied. Consequently firms generally innovate within one industry or within one type of products (Pavitt 1984). Doing so eases the process

of surviving and succeeding in a market economy. When firms set out to find, develop and evolve their technology, they typically proceed through trial and error until they discover or create their niche within the industry (De Marchi, Napolitano et al. 1996).

According to Dosi (1982) there exist, at a given time, a set of interrelated and widespread radical innovations that combined form a technological paradigm. Firms generally innovate in accordance with the existing paradigm. In this context technology is referred to as problem-solving activity, where the problems are stipulated by the current paradigm. The existence of a given technological paradigm is dependent on how the technology evolves. The incremental changes to the existing lines of technology within the paradigm are defined as technological trajectories, according to Dosi (1982). These lines of technological change and evolvement may start with an entrepreneur, who either discovers or creates an opportunity. This line proceeds to evolve within a firm as the firm's routines, knowledge and structure develops. The development of a technological trajectory is thus parallel to the development of the specific technology of a firm.

It is possible for a technology to get locked-in within one trajectory, if the routines, markets and the industry surrounding it fail to adopt external ideas. Further, due to underlying trends and routines, some trajectories are more likely to develop than others. Andersen (1998) referred to technological trajectories as lines swerving their way through industries and society. The same concept may be deemed applicable at an organisational level. If a firm experiences lock-in, the firm's technological trajectory is likely to stagnate as well. A continuously input of external ideas and contact with complementary firms are necessary to maintain and evolve a firm's technological trajectory.

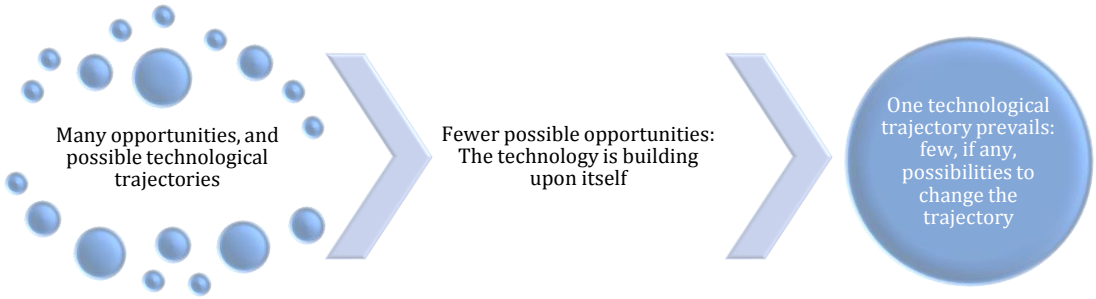

Figure 3 The course of a technology trajectory

A paradigm incorporates strong suggestions regarding what directions of technological change a firm ought to pursue and to disregard. This marks the setting for which direction companies develop their technology. For a technological trajectory to survive it needs find its place in the market by building upon the standards for what is considered progress. Once a firm's technological direction has been chosen, the direction takes on a momentum of its own and moves along a natural trajectory of technical progress within the bounds of the paradigm, and also within the firm's available resources (Dosi 1982).

The technological trajectories Dosi (1982) describes bear a strong resemblance to the theory surrounding path dependence and lock-in. The technological trajectory is the path which new technology follows as it continuously undergoes incremental changes, and gradually becomes more and more dependent on previous choices. The degree of lock-in may play a role when it comes to the adaptability and transferability of existing technology. This is, in particular, important whenever a firm is altering or completely changing its technological trajectory. Another principal matter in this regard, is how specialized or general the firm's technology is. A broader, more general technological trajectory may be more tolerant of change.

If a technical problem proves to be impossible to solve, it does not automatically indicate that a firm will change to a different path. The two concepts of technological trajectories and paradigms are representative metaphors for the continuously interplay of the start-and-stop process of incorporating knowledge and technology into industrial growth. Typically, technological development in firms' undergoes a nonlinear process before resulting in an innovation ready for the market. It should

also be remembered that economy, routines and social factors also play a part in shaping the development of technological trajectories and firms (Dosi 1982). The processes of technological innovation and trajectories are all in all very varied and complex (De Marchi, Napolitano et al. 1996).

Pavitt did in his work from 1984 list what he considered to be determinants of technological trajectories. These determinants were categorized based on technology source (whether it be R&D, design and product engineering, suppliers, etc.), whether the user was sensitive to price or performance, or by what means the technology was acquired and preserved. Four patterns for technological change can be drawn from these features, and Pavitt named them supplier dominated, scale sensitive, specialized suppliers and science based. From this classification it follows that firms having their core competencies within a specific industry, will follow a particular technological trajectory.

Note that the concept of technological paradigms has been repeatedly used in this section. The concept was used to better understand and illuminate the existence and nature of technological trajectories, and also to see the value of trajectories on a grander scale. However, paradigms will not be referred to in the later analysis of this thesis. Due to the short lifetimes of the cases used in the analysis, discussing the long perspective of paradigms will be less relevant.

2.5 Networks of organisations

This chapter has so far considered path dependence in organisations by discussing the technological trajectories that organisations follow and the types of knowledge that organisations may possess. A more external aspect of organisations is their networks, and how the organisations relate and interact with their environment. To keep a path broad, external influences are required. Thus to create new innovations or to recombine old technology, this influence should come in addition to those impulses generated within the closed loop of one organisation. One of the main factors that affect an organisation’s ability to collaborate with external actors relies on the cognitive distance of the involved parties.

Cognitive distance revisited

Cognitive distance was introduced in section 2.3 due to its importance when trying to combine different knowledge types internally within an organisation. When considering inter-organisational relationships this concept is once again relevant. On the inter-organisational level differences in organisational culture may lead to a cognitive distance between organisations (Nooteboom, Van Haverbeke et al. 2007).

How is the relationship between cognitive distance and innovation performance? If the cognitive distance is too large, the organisations and people will preclude the mutual understanding, which is necessary for collaboration. On the other hand, if the cognitive distance becomes too small, the innovative capacity may be reduced as organisations and people are too similar or familiar with each other. The desirable optimal cognitive distance lies somewhere in-between the two extremes. At this point, the cognitive distance may have a positive effect on learning by interaction. Consequently the different knowledge and skills of organisations and people will expand their knowledge by trying to bridge the cognitive gaps (Nooteboom, Van Haverbeke et al. 2007).

According to Nooteboom, Van Haverbeke et al. (2007), the positive effect of cognitive distance will be higher if the organisation in question is explorative and more radical in its innovation process. This situation will force an organisation to search beyond its existing networks to find needed novelty and make new combinations. Similarly, this positive effect of cognitive distance will be lower for organisations with exploitative and more incremental innovation processes. Further, resource heterogeneity as well as an optimal cognitive distance, provide a greater potential for innovation and learning. Explorative innovation processes and resource heterogeneity requires a higher absorption capacity for an organisation.

Local buzz and global pipelines

Cognitive distance can be made more solid by taking a closer look on organisations' networks with the local and global community. A concept assisting in defining the knowledge term of a company's network is *local buzz*, which is place specific and unique for each company. This buzz refers to the ecology that is created by interaction, face-to-face communication and the presence of both individuals and

firms within the same region or industry. The buzz creates an open communication, which provides a continuous information stream regarding technology and markets, as well as a further understanding and knowledge of the community. This model of communication is based on social norms and trust. Seeing as local buzz's only requirement is for the involved parties to be present, it thus follows that this model has low costs (Bathelt 2004).

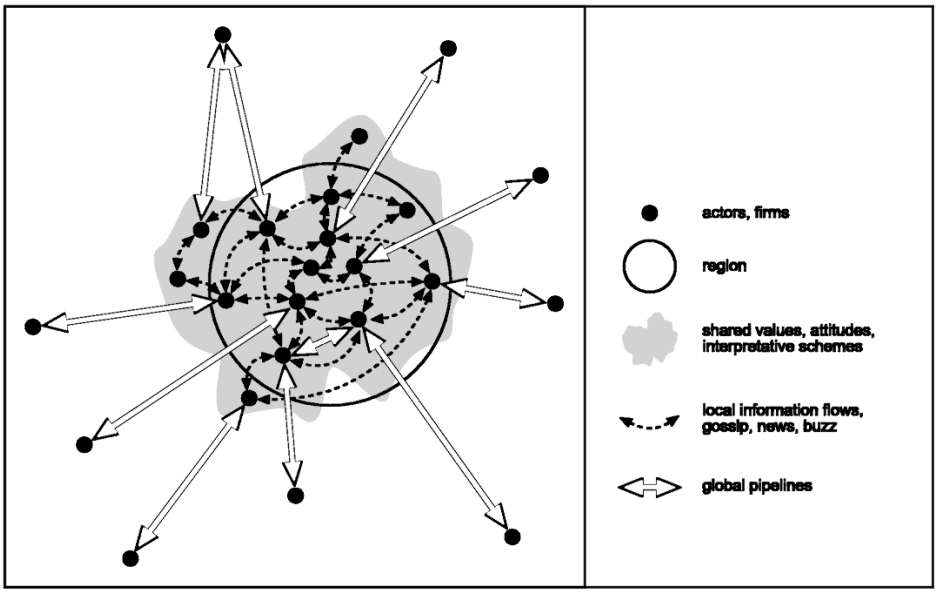

Figure 4 Local buzz and global pipelines ***(Bathelt 2004, p. 46)***

Local buzz also presents a possible problem, which is a cognitive lock-in. This is due to the fact that there is a limit to how much knowledge can be extracted from a bounded system. In this case, having external contacts are essential, and may be described by the opposite term: *global pipelines*. However, these channels for information and communication are often strategically planned networks or partnerships. Global pipelines are critical for acquiring knowledge about markets, technologies and innovations in other environments. This mode of contact needs to be organised and managed, and in addition, taken into account regarding the cultural and social differences between communities (Bathelt 2004).

Systems for developing, exploiting and sharing knowledge all have their place in organisations. This is made evident by the networks and relations of organisations. Networks are likely crucial for radical technological development to take place.

Bonding and bridging networks

When it comes to building networks and relations, there are two other complementary concepts to local buzz and global pipelines. These concern who the local or global partners are. *Bonding networks* are about relations between similar actors or companies, i.e. among organisations that are cognitively close. These networks contribute to enhance and further develop established knowledge of the involved parties. The other concept is that of *bridging networks*, which concerns the relations between parties that differ from each other, and which may provide new knowledge and perspectives. Interactions between similar companies tend to lay the foundations for incremental innovations, while radical innovations are often the result of bridging networks (Jacobsen and Lorentzen 2013, p. 182). When collaborating via bridging networks, it is important that the difference between the companies are not to great, as that may culminate in a negative cognitive distance.

Transaction costs

To conceive of a company's interaction pattern words like relations, network and knowledge sources are often used. What parts of a company's relations are targeted towards cooperation for innovation? According to Jacobsen and Lorentzen (2013), being innovative requires collective achievements from numerous actors, and more specifically, it places weight on a company's network. One angle of approach is to look at transaction costs, which values how economic activity is organised through different links in the production line. Transaction costs thus concerns what is being done internally in the company, what is outsourced through network, and lastly what is done through ordinary market transactions. The transaction costs are specific costs that are associated with carrying out these activities. Organisations and companies have a varying ability to handle these transaction costs. Larger and more established companies may have better conditions for carrying out more complex collaboration activities than smaller companies with fewer resources.

Other aspects to consider in relation to transaction costs and how companies operate and collaborate to promote innovations may be trust and culture. For example, if the parties are expected to work together in a specific way, this will likely affect how they act. Hence, current routines play an important role for how companies may work together (routines may otherwise be termed as economics of sociology). Path

dependency, previous experience and knowledge of the involved parties are also a part of how companies act when entering into cooperation's for innovative work (Jacobsen and Lorentzen 2013, p. 178).

2.6 Technological innovations and path dependent development in firms

The characteristics of technology advancement and organisational path dependency may have their roots internally within organisations in the organisations' knowledge, routines and technological trajectories, or they may originate externally through networks. Technology development may occur through great leaps or through many small steps. Thus, we may differ between radical and incremental innovations.

Radical and incremental innovation

The innovations that disrupt current technology, i.e. radical or major incremental innovations, may have the ability to erode a path or completely change its track. For radical innovations to be created and to triumph over existing technologies, impulses from outside of local existing networks are often needed (Rycroft and Kash 2002). This is in accordance with Laursen and Salter's (2006) finding companies with more open searching strategies to gain new impulses and knowledge, tend to be more innovative. Even so, such open strategies are only beneficial up to a certain point, after which the possible knowledge gain becomes less than the input effort.

Radical innovations may concern drastic changes to technology, perhaps to the point of a technological paradigm change. Incremental innovations however, is concerned with smaller changes and continuously improvements to existing technology. While radical innovations may have far reaching impacts, the cumulative impact of incremental innovations may be just as great. For instance, for a radical innovation to reap economic benefits, a string of incremental improvements are often required. It might even be argued that the major part of any financial benefit stem from incremental innovations (Fagerberg 2005, p. 7-8).

Radical and incremental innovations require different capabilities of organisations. The first requires an organisation to ask different questions, to use new technical and commercial skills, to find new ways to approach problem solving, and perhaps to tear down the present competences. As incremental innovations rely on the expansion of

known knowledge and the use of available resources, they may strengthen the existing abilities of an organisation. As opposed to radical innovations, incremental innovations will make sure the existing products in the market remain competitive. A generalisation regarding which type of organisation is initially better suited for conducting radical versus incremental innovations can be made. Established organisations will likely be better positioned using existing knowledge and resources, and therefore often favour an incremental innovation process. However, new organisations will often have a better edge if their innovation process is radical, since they will not need to change their knowledge background. (Trott 2012, p. 213)

Traditionally highly specialised clusters of companies have been seen to be competitive. However, Isaksen and Karlsen (2013) emphasise the importance of diversifying a region's knowledge bases. Their point is that a less specialised and more diverse knowledge base may promote and encourage linking to related knowledge. I consider this to be a relevant aspect internally in organisations as well. So a congregation of complementary knowledge may, when pooled together, create additional superimposed knowledge.

Market forces or technological forces?

When discussing driving forces for innovation and technological change, it is common to distinguish between the two rough categories of "demand-pull" and "technology-push". The demand-pull of technology is generally due to the effect of market forces, i.e. the development and change of technology is the result of an already expressed market need. In opposition, the technology-push stems from an innovation being pushed through R&D, followed by the commercialisation process and released into the market. A technology-push does not take into regard whether or not there exists any specified market need it is obliged to satisfy (Dosi 1982). This presents a rather linear and one-dimensional view on technology-push and demand-pull. An extension of this notion is that the investment in R&D increases a company's knowledge base, and thus expands that company's ability to adopt, absorb and exploit knowledge and opportunities from other sources. (Nemet 2009)

A theory of innovation ought to aspire to explain major and minor technological breakthroughs, not just incremental changes to existing technology. Demand-pull is

based on there being an obvious market need, which will initiate the generation of R&D that will lead to the next innovation. However, a market need is a vague description, and could in theory include an infinite amount of possibilities. How can a vague demand explain why an innovation occurs? It is generally accepted that "*market is important in determining successful innovations*", however, whether market needs are the primary instigators for innovative activity is not clear. (Dosi 1982) The process leading to a change in technology or to new innovations, presents itself as a highly complex one, and to some degree riddled with uncertainty.

Path status

When discussing what characterises the innovation activity of firms and the evolution of their path, we may differ between three alternatives; path extension, path renewal or path creation (Martin 2010, Isaksen, Abelsen et al. 2013). The path status for a given firm will depend on the degree of path dependency and the type and degree of lock-in the firm is experiencing.

The first option may be described as *path extension,* and portrays a firm enhancing its existing strengths. The intention of this process is to make the firm's unique qualities more competitive. Becoming too specialised is a danger when extending a firm's path. The path might deteriorate and wither away. The second option is *path renewal,* which entails a firm broadening its product portfolio by starting up production of similar products. Renewing a path in this manner relies on existing knowledge and on the recombination of existing knowledge. The third, and most far-reaching option is *path creation* through the breaking of existing path, which includes either a complete turnabout by existing firms, or the creation of new firms which may operate in a different manner from the older, more established firms. A firm or an industry is not likely to pursue path creation unless it is experiencing a strong form of negative lock-in. The concepts of path extension, path renewal and path creation may be used to describe and understand both industries and organisations. I have chosen to apply them at the organisational level.

Technology development may stem from demands in markets, or from a new technology pushing its way into daylight. The characteristics of technology development are many. Firms may have their own way of evolving technology, but

common features recur. However, the main features in conjunction with technology development may be the knowledge surrounding technologies and firms, the technological trajectories, the inherent routines of firms and the reliance on internal and external networks. These are the individual components technology development consists off. The degree of path dependency and self-reinforcing mechanisms describe the path the technology will undergo. To begin to understand what drives and characterises technology development, the underlying components need to be analysed individually and as a whole. The questions to further analyse is how these components are connected, how large their roles are and how technology development differ between firms.

3. Method

The method presented in this section has been chosen to best suit the research questions and theoretical framework of my thesis. The research design, data collection and selection of cases are the three main aspects of the methodology, and will be discussed in detail.

A case study is according to Yin *"a linear but iterative process"*. This statement roughly describes how I have worked to plan, design, prepare, collect, share and analyse my thesis. (Yin 2014, p. 1) The process began when I participated in the ACCEL Subsea First Step program during the fall of 2013. The purpose this seminar held for me, was the opportunity to get a glimpse into how firms, in real life, design their innovation strategies. I here came into contact with APIteq, and the company showed interest in me writing my thesis in combination with them. In the months following the ACCEL program, I finally decided to write my master thesis around the subject *"characteristics of technology development"*.

3.1 Case study and the comparative method

The background for my empirical material in this thesis will be a comparative qualitative case study. According to Schramm 1971, it is at the core of a case study that the study aims to shed light on a decision or a set of decisions: why were precisely these decisions taken? How were they conducted, and with what result?

(Yin 2014, p. 15) This statement correlates to my research questions of what the characteristics of technology development are.

To gain insight into how firms operate and the processes that guide and determine technology development, I have deemed it best to use the qualitative method for illuminating my research questions. This method allows for detailed answers and in-depth study of an objective, namely the four companies that have been chosen through a strategic selection (additional info regarding the selection of cases is presented in section 3.3). The characteristics behind technology development may be many and varied. The alternative of a quantitative method would have greatly restricted the speech of the respondents, as a quantitative survey may merely require ticking off short predetermined answers.

As Swanson stated in 1971: "*Thinking without comparison is unthinkable. And, in the absence of comparison, so is all scientific thought and scientific research*" (Ragin 1987, p. 1). In social science the term 'comparative method' often refers to comparing units on large macro-social scales. This is also the basis of the method used in this thesis. The units that I will analyse are thus the case companies, and to obtain the necessary information I will need to gather data on an individual level.

As mentioned, this study seeks to study the characteristics of technology development in the cases, see how the cases have developed, what is similar and what is different, and proceed to discuss whether they may benefit from their mode of technology development. An approach of taking a slight look at the historic perspective, before diving in to compare the present and the future, is in accordance with how comparative studies often are done (Ragin 1987).

In 1843 John Stuart Mill presented two methods with relevance to case-oriented studies. The first is the method of agreement, which searches for patterns of invariance by the process of elimination. This method, however, is somewhat incapacitated in the case of multiple causation, as it will remove the option of pairing two variables or cases to reject a third case. Mill's other method, the indirect method of difference, may be more applicable to use in this instance. This approach assumes two scenarios: one case where the point of interest is present and one case where it is

not. In accordance with this thesis's subject, Mill then says these two cases have everything in common, save for one variable, and this lone variable is the cause or the effect that differs the two cases (Ragin 1987). This paper tackles four relatively similar cases, and Mill's indirect method of difference will be used. However, it is likely to be more than one underlying variable resulting in different or similar performances for the chosen cases. Mill's methods may appear problematic with regard to multiple-causation, and are in reality more often used as rough guidelines than as a rigid method for case-oriented research.

In practice the method of difference will for example be: Case X and Y differs, but both experience Z. What is the underlying cause, and is this cause founded in similarities between X and Y? This is an inductive method as initial theoretical perceptions serve as guidelines for finding similarities and differences. In the end, the induction may culminate in the elaboration of initial theoretical ideas, and perhaps also radical new concept formation. The process is rarely straightforward in practice, as the cases often are complex and similarities may not be obvious (Ragin 1987, p. 45). Its relevance to this thesis would be how several, or all of the cases, were found to be path dependent.

Another situation concerns apparently similar cases with different outcomes. The clue in this case is to identify the reasons generating the different outcomes. The situation also supports itself on a theoretical framework to find the causes relevant for producing a different outcome. The difference is then the basis for formulating an explanation (Ragin 1987, p. 47). In this thesis the difference may be the degree of organisational path dependency the cases experience.

An effect to watch out for when performing a comparative case study is that of illusory commonalities. They exist whenever two or more features appear similar, but in reality their effects differ. It therefore becomes important to analyse similarities and differences in context (Ragin 1987, p. 48-49).

Cases are examined as wholes, and case studies make it possible to get an extensive dialogue between original ideas, theory and the empirical material. The comparative case study is most easily carried out when the number of cases is relatively small.

This is due to the possibility of the study becoming difficult to manage as the number of cases and number of possible comparisons grows (Ragin 1987, p. 49-51). Four cases, as in this thesis, are considered manageable.

3.2 Data collection

Since this is a comparative case study consisting of four cases, the ideal research method to use may be perceived to be a combination of a quantitative and a qualitative study. However, this is considered to require a too extensive data acquisition and analysis for the scope of this thesis. Therefore, the gathered data material in this study will be qualitative.

According to Easterby-Smith (2012) there are three main categories for collecting qualitative data: language data, observation and interaction. The first method may refer to doing an interview, which was the main way of collecting data for this thesis. Even so observation and interaction may also play a part, and written information about the cases and their practices will also be used.

The method used for gathering data was semi-structured interviews, with a mix of open questions, to better maintain an objective and neutral perspective, and with more specific follow up questions. In preparation to the interviews a case study protocol was set up. This is essentially a questionnaire guide with a list of relevant questions (Yin 2014, p. 84-85). For the interviewer, the purpose of the guide is to help direct the interviews and reveal areas of interest. I used the question guide to some degree during the interviews. However, as the interviews progressed as conversations I seldom followed the guide, but rather used it more as guidelines to make sure that the interviews touched upon all the relevant subjects. The question guide may be found in the appendix.

The respondents/participants of this study was key-persona in the selected companies, preferably the CEO or founder. Such persons were chosen because they might give a broader and more knowledgeable insight into the companies' situation. To avoid having to rely on notes and memory during the interviews a recorder was used. The responsibility for when this was switched on and off was in consensus with the interview object; this was done to make the respondents more at ease with the

interview situation. The timeframe of the interviews were roughly one hour each, and all of the interviews were done in a conversational manner. It was optional for the respondents whether the interviews were conducted in English or Norwegian. All of the interviews were executed in Norwegian, and any quotes used in the subsequent sections of this thesis will be translations.

I transcribed all of the interviews after having recorded them; this was done so that I could do a more detailed analysis. I experienced all of the interviews as positive settings, and all of the respondents encouraged me to contact them again if I had any follow up questions.

The cases will be referred to by company name. Respondents who participated in the interviews are anonymised according to their wishes. The respondents may thus be referred to as a founder or as a representative of a given company. Four interviews were conducted, one with each company. APIteq, Epsis and Stormfjord all had one representative each for the interviews, while Scantrol had two representatives.

Doing interviews as a method of gathering data has a set of given strengths and weaknesses. Yin (2014, p. 106) lists the following strengths: interviews are targeted by focusing directly on topics of interest, and they are insightful since they allow for explanations as well as personal opinions and reflections. The critique of interviews as a form of gathering data is, according to Yin, the fact that there may exist a bias due to poorly articulated questions, and also in the response of the participant. The latter is shown through reflexivity, meaning that the respondent answers what the interviewer wants to hear. A final weakness may be inaccuracies due to poor memory of the interviewer; this has been avoided by the use of a recorder during the interviews. As for the other weaknesses, I have tried to minimize them to the best of my ability, and the data material will in addition be questioned in the following analysis and conclusion.

Since I am doing a comparative case study, the collected data material is too narrow to be used for empiric generalisation. Empiric generalisation is connected to the external validity, i.e., whether or not the study's findings can be applied to a larger population. Seeing as my thesis is an in-depth study of a few selected cases, the

external validity will on a general basis be low. However, the thesis can be used to further illuminate the theoretical aspects surrounding technology development and path dependency through an analytical generalisation. Analytical generalisation of a case study may be based on one of two things. The first concerns the finding of new concepts while conducting the study. The second concerns a commentary, discussion, rejection or advancement of theoretical concept that has been presented in the study (Yin 2014, p. 40-41). This thesis will be used to further solidify and elaborate the theory presented in chapter 2.

To increase the reliability of the thesis, quotes from the interviews will be frequently used in the analysis. This will help give credibility and validate the empiric material. A concept, which concerns the external reliability of a qualitative study, is whether or not the gathered data may be replicated. Replication may be difficult to achieve in qualitative research, as it calls for independent relations between the researcher and the respondent. Respondents may also reply differently at a later time. The reliability in this case must then be connected to a detailed account of the research process. (Thagaard 2009, p. 198-200) I have strived to do so by describing my approach in the current chapter.

Giving a detailed overview of how the research was conducted makes it possible for others to consider the research process in its entirety. This makes the research transparent, and thus increases the internal reliability. The review of the theoretical framework in chapter 2, represents the foundation for the further analysis, and also makes the thesis theoretically transparent. (Thagaard 2009, p. 199)

I have also received guidance from my supervisor at Bergen University College. Including him in the research process has allowed me the opportunity to discuss my thesis and receive constructive criticism during my research.

Seeing as I do not have in-depth knowledge about the industry the selected companies operate in, it has been difficult for me to accurately evaluate how broad or narrow the companies product portfolios are.

Bergen University College has previously conducted interviews with three of the selected companies I have chosen to analyse, namely Epsis (in 2012), Scantrol (in 2011) and Stormfjord (in 2013). The topics for these interviews were different from the focus of my thesis; nevertheless the transcripts from these interviews were made available to me. I have just to a small degree used information from the previous interviews to supplement my analysis regarding the history and networks of the cases.

3.3 Selection of cases

This thesis aims to look at the characteristics of technology development, and as such I had to set up some parameters limiting my selection of possible cases to consider and analyse. The first and mayor selection criterion is that the companies in my selection work within the oil and gas industry. The reasoning for this is for the cases chosen to operate within the same markets and perhaps have some similar technology knowledge and background. The second mayor selection criterion is that the companies chosen will be relatively young and small to medium sized (1-100 employees). A third selection criterion is that all of the cases are located in the same geographic region; in this case namely Bergen, Norway. Finally, the cases are presumed to be innovative.

Initially, I wanted to choose two cases with a presumed analytical knowledge base and two cases with a presumed synthetic knowledge base. Making such assumptions before getting to know a company was difficult. Doing so would have made the categories very rough and broad, and prone to change during the analysis.

Bergen University College, where I am currently a student, assisted me in finding relevant cases, and based on this I eventually decided on three of the cases: Epsis, Scantrol and Stormfjord. The last case, which is used in this thesis, is APIteq, a company that I came into contact with during the ACCEL Subsea First Step program, hosted by BTO during autumn of 2013.

This selection of relatively similar cases, but where each case has one, or more, differing variables from the other cases, will provide me with comparison parameters. I will then be able to look at similarities and differences between the cases. I expect

this to give me insight into how the companies' technological trajectories and organisational paths have developed.

4. Analysis

The analysis aims to shed light on the characteristics of technology development by studying the four companies in detail. Doing so, requires looking at what role path dependency plays in technology development. This entails a study of the components comprising organisational path dependency, namely the firms' technological trajectories, the knowledge the firms possess, their routines and their network. To discern the similarities and differences of technology development in the selected firms, they will be compared. Lastly, my analysis of the components comprising organisational path dependency will be used in a discussion of the degree of organisational path dependency in the selected firms.

Each section of this analysis will first analyse each of the cases by themselves, and then consider them in comparison to each other. The cases are in general discussed in alphabetical order. Empirical data used in the analysis is based on the interviews. As all of the interviews were primarily conducted in the Norwegian, quotes used in the following sections of this analysis have been translated.

4.1 Presentation of the selected firms

This section will present the four companies and their technology: APIteq, Epsis, Scantrol and Stormfjord. This part of the analysis will give an overall overview of the companies' history and development from their infancy. The involved parties background, education and industrial experience will also be mentioned. These points are included with the purpose of better explaining the companies' degree of path dependence later on. This part will be descriptive, as a more thorough analysis and link to theory will follow in the subsequent sections. The logos of the firms are shown below.

4.1.1 APIteq

APIteq (Action Photo International – technology and quality) was founded in 2005 by two people and is located at Straume, Sotra, Bergen, Norway. From the start the company has worked with 360˚ panorama photographs and solutions. APIteq started out in the hotel and boat industry, and from 2008 they started working towards the oil and gas industry, which is their primary industry/market focus today. They have produced the software and camera system that they use in collaboration with their partner Weiss AG in Germany. Today APIteq has in total 12 employees, 10 in Bergen, one in Houston Texas and one in Rio, Brazil.

APIteq's 360˚ PanoramicGuide is the core product of the company. It is a visualisation and communications solution based on photographs and video, which can be operated from any computer. This tool provides the ability for a company operating from several locations, whether onshore or offshore, to simultaneously see the entire installation by use of high quality panoramic pictures, interactive maps, menus and navigation capabilities. The company has the goal of enabling uses to "See everything – from anywhere". (APIteq 2014)

Two others, who initially worked with establishing a 360˚ photography company, incidentally introduced the two founders of APIteq to the basic 360˚ technology. Their start-up failed. However, the founders of APIteq learnt in the process enough to understand the potential of the 360˚ technology; like who the customers were, the size of the market and where to get camera equipment, software, etc. Through their learning process the founders of APIteq realised this was something they would be able to do, as well as something they wanted to do. Not having a special interest in photography, the idea of a business opportunity first presented itself after they had been introduced to the technology through acquaintances. A firm representative explained the company's start as:

"It was quite arbitrary that we were introduced to the 360˚ technology. We really wanted to start a company, which would give us an opportunity to create something new."

When the company started up in 2005 it mainly targeted the hotel industry and boats, i.e. sales and marketing of leisure boats/yachts. Their customers at that point used their 360˚ technology as a marketing tool to present themselves online, and even as a new way of doing things. The company got by on a mix of skill and luck in the beginning, and consequently they managed to acquire a lot of business during the first few years. This can for example be illustrated by a contract that APIteq acquired with Choice Hotel Scandinavia for all of their hotels. Within the first few years APIteq did a total of 120-130 projects.

In 2009 APIteq came into contact with the person who is their present Chairman, a person with long experience from the oil and gas industry and also from developing successful companies. The two founders do as mentioned; have a lot of experience from the petroleum industry. It was a deliberate decision when APIteq in 2010 directed all their efforts and focus towards the oil and gas industry, thus leaving the hotel and boat industries behind. They did their first project in the oil and gas industry for Archer (formerly Seawell) at the Veslefrikk platform, and more assignments and contracts followed. The response convinced them there was an opportunity for making a documentation tool enabling APIteq's customers to sit onshore viewing what everything at different installations look like, and the customers may thus save travels offshore. APIteq started marketing this, and at OTC (Offshore Technology Conference) in Houston the response was solely positive. Regarding their project at Veslefrikk a representative for APIteq said:

"This market opportunity would never have appeared if not for the background that we have from the oil industry."

Following APIteq's participation in the ACCEL Subsea First Step program during autumn 2013, the company started doing a subsea project. The aim of this project is to make use of the technology they commonly use topside on oilrigs today, and try to develop a system that may do similar 3D measurements and visualisation subsea. Whether they move forth with this will depend on the participation of possible customers, and if successful, this subsea project is expected to reach commercialisation in 2017.

4.1.2 Epsis

Epsis was founded in 2003 and has its main offices in Bergen, Norway. Today, Epsis also has departments in Stavanger, Norway, and Houston Texas, and is also represented in Aberdeen, Scotland. Today the company has 35(??) employees, and experience that their technology has more applications than first intended.

In the 1980s the founder of Epsis was among the first to get a degree within petroleum technology, as petroleum research was a new field in Norway at that time. Through his career the founder of Epsis acquired a broad background from academia due to an education within petroleum technology and physics, as well as through two professoriates. Intersecting his time with academia he also gained over 20 years experience from the oil and gas industry. The founder started (around year 2000) to work with integrated operations, which concerns making quicker and better decisions within the operational environments for oil and gas activity. The concept of integrated operations also means for different engineers to be able to collaborate across disciplines.

When founded in 2003, the company worked closely with the customers to figure out what exactly integrated operations were. This was the precursor for the generic product Epsis has today. The product has turned out to be a management software solution that eases meeting workflows and sharing of information. (Epsis 2014)

From initially only seeing the oil and gas industry as their market, Epsis has in later years realised that their technology may be of use in other industries as well as having more applications than first intended. The possible new market segments include the healthcare sector, the public sector and the Norwegian Correctional Services.

From being a company with a heavy focus on industry knowledge and initial development of their product, Epsis has in later years phased out and reduced this part of their company. This is because they now have a stable and generic product line, and the company now seeks to gain a larger market share through focus on sales and marketing.

4.1.3 Scantrol

Scantrol was officially established in 1988, but was originally a part of Scanmar, a company that made sensors used in trawls. The two founders of Scantrol originally working for Scanmar, both have backgrounds from engineering, and in the late 80s they got a few good product ideas that did not fit with the profile of the company they worked for. The founders then made contact with a company in Tønsberg that made products complementary to their ideas. Together they created a new company, with a shared ownership for the first 3 to 4 years, before Scantrol became independent in 1994.

The two founders perceived the process of breaking out from the parent company with a new idea as unproblematic. The new company, Scantrol, started making a winch control system for fishing vessels and marine research. During their development process they received feedback from potential customers, thus making it an interactive process. However, the customers did not participate in financing this process, and Scantrol decided to do all the development in-house or in collaboration with the Research Council of Norway and the Institute of Marine Research (IMR).

Scantrol is located in Bergen, Norway, and delivers electronic control systems to the offshore market, the fishing market and the marine research market. The company originally consisting of only two founders now have 17 employees, and a wide range of partners all over the world.

Perhaps the main product that Scantrol delivers today is the Active Heave Compensation Systems (AHC) for launch and recovery systems. AHC eliminates vessel motion transferred to the load, reduces operational time for subsea operations, and may be used with both old and new winches and cranes. In addition multiple systems on a vessel may use some of the same infrastructure to reduce cost. (Scantrol 2014)

4.1.4 Stormfjord

Stormfjord was founded in 2007 and has its offices in Bergen, Norway. One of the founders got the main idea behind Stormfjord roughly 25 years before the company's start. Back then the founder worked in Statoil, at Mongstad, and started to envision

some 3D and visualisation solutions to better teach others how things work. During the founder's employment at Statoil, he had the opportunity to get an education in physics at NTNU (the Norwegian University of Science and Technology). Afterwards he moved on to get a doctorate, and eventually became an associate professor at NHH (the Norwegian School of Economics). While working part-time for Statoil, the founder collaborated on a research project through the Research Council of Norway. During this time he discovered a business opportunity in the market. At this point the founder had accumulated a substantial amount of knowledge regarding 3D and visualisation solutions. He was himself a user of what he wanted to improve. So, together with a co-founder and with support from Statoil, Stormfjord was founded. When founding the company, the founders had a continuous dialogue with Statoil, and during these dialogues, Statoil showed their interest by saying that they wanted to buy licenses from Stormfjord.

The founder of Stormfjord describes the company's history as: *"We had been working on our product during a long time before start-up. Only two months after founding, we had our first version of our product on the market. We have had many versions of our product, and it is actually just now, seven years later, we have managed to stabilise the software. Finally, we also have a market more prepared for our products. The process has taken quite some time. If we had kept our focus more strongly on the basic idea that I had as a 19-year-old, which we have now returned to, then we probably could have delivered a minimum version of our solution much earlier."*

Starting up a company in 2007 would prove to be less than ideal for Stormfjord. Stormfjord had a research project going on, and the company was supposed to have continuous 3-year projects together with Statoil. The timing did initially look very favourable for the company, however, after eight months the financial crisis struck, their partners' projects closed down, making the following period very turbulent for Stormfjord. For the founder – a technologist, physicist and researcher – experienced the start of a steep learning curve having to learn to navigate a company at a difficult time. From this challenge he gained valuable experience and personal development.

From founding, it took roughly 5 years before operations started going smoothly for the company, and at around the seven-year mark Stormfjord started to get growth. According to the founder there are two things that are necessary for starting a company, and that is *"to start and to endure"*. In 2008 the company was granted membership in the incubator "Nyskapningsparken", which was a great help when dealing with the everyday challenges that new companies face. Stormfjord retained this membership for four years.

The 'stayer' mentality is important for Stormfjord when meeting rough waters. When being in the process of establishing offices in Spain during the past year, Stormfjord's subsea offices in Stavanger unravelled, and the company had to shut down their section there. This resulted in their staff being downsized by four people. Today Stormfjord has four employees. At present there are also one PhD student as well as six bachelor students associated with the company. Usually they also have a couple of master students.

On the technical side, Stormfjord is today a software company that seeks to create high quality 3D visualisations and simulations. The company transforms industrial data into solutions for interactive use and facilitates visualisation and manipulation of 3D CAD models. The technology developed by the company has enabled automated treatment of 3D data of any format, no conversions, direct access to 3D data, openness and no loss of information. This handling of 3D data makes it more accessible for operations, and also increases the quality and value for customers and partners. (Stormfjord 2014)

4.1.5 Comparison and commentary to the presentation of the firms

There are many similarities among the histories of the companies. They have more or less all gone through challenges that are common for small start-up companies. APIteq, Epsis and Stormfjord have all been introduced to the technological concept base for their companies through previous work experience. Scantrol also bears traits of having such a background.

The founders of Epsis and Stormfjord have a substantial background from academia, and the founders of all four companies have either an education in engineering or

experience with engineering. The founders still have top management positions, they have in-depth knowledge of their company's technology, and have also managed the transition from being an engineer or researcher to leading a company and all that may entail. Though some of the founders have long experience from academia, none of them do currently exhibit strong ties to their former R&D institutions.

Scantrol is perhaps the company with the strongest focus on doing R&D in-house today, and also the only one of the four companies actively operating in three different markets. The other companies acknowledge a potential for their products in other markets, but have still to direct their main attention towards establishing themselves in those additional markets.

Software features are an important component of all the companies' technology, and to some extent the development of their technologies has been done in-house. Relatively quickly after founding, all of the companies were able to enter the first version of their products into the market commercially. To help fund their development the companies have in addition done consultancy activity. Thus the majority of the companies were able to receive an income almost from day one.

This presentation of the companies and their history will lay the premises for the rest of this analysis.

4.2 Technological trajectories

The process of technology development will be considered in this section. This will include the technological trajectories of the companies, the placing of their technology in the market and the existence of similar technologies in the market.

4.2.1 APIteq

What APIteq did when they decided to start the company was by no means revolutionary. The founders saw and grasped a market opportunity that seemingly anybody could have taken, that is not to say that anybody could have done so. This was the start of APIteq's history; they gained knowledge of a technology, discovered a business opportunity and proceeded to develop their product. In this sense APIteq

roughly follows the three stages of the development process that an innovation or a technology usually go through.

Since the start APIteq has kept their main product relatively stable, and continuously done improvements and incremental changes. In particular this concerns IT, processing of photographs and new software. The company mainly experiences major changes in conjunction with larger technology development projects. APIteq does not envision to develop their technology in other technological directions, but the company is slowly starting to consider a few other markets outside of the oil industry, this is for example Kripos and crime scene investigation, as well as different types of energy companies, i.e. hydropower, nuclear power etc. So in terms of potential markets there are a multitude of possibilities, and APIteq has chosen to focus and excel at a selected few. This ensures that the company does not "bite off" too much at a time.

As mentioned earlier, as APIteq continues to grow, they will continue to build upon the technology that they already have developed. In this way they have decided to let their technology follow one trajectory and one direction. There are mainly two reasons for this, one is due to a limited capacity and availability of resources, and the second is due to the competitive advantage that lies in having a head start and keeping it.

The transferability over their current main product, the 360° PanoramicGuide, makes it highly likely that APIteq will branch out into other markets. While they stick to their main technological trajectory, this trajectory will have several smaller branches consisting of similar technology.

Though the 360° PanoramicGuide is the company's main product, APIteq considers their main innovation in the span of the last three years to be their Visual Asset Management software (VAM). The company itself has been using this software since 2012, and the version being delivered to customers was finished at the beginning of March 2014. APIteq is further broadening its technological scope by starting up a subsea project during 2014.

Both the VAM (Visual Asset Management) software and the 360˚ PanoramicGuide are the results of a discovered market need. The company would never have moved forth with any of their development projects unless they had known from the beginning that it would acquire interest from customers. Finding, acquiring and understanding the needs of customers at an early stage is more favourable for the company than exploring what may appear to be a good idea on their own. They rely on customers for directions and ideas in finding their technological trajectory and for collaboration during the development process, or as a representative of the company stated:

"In our experience, the customers are not the innovative party even though they may think so themselves. The situation is rather the contrary; they are very conservative. They think innovation is their field of speciality, which it isn't."

For APIteq the innovation process is no formal process, it is more a company culture; being able to be share and be transparent about everything from small improvements to grand ideas. According to APIteq, being willing to take risks is very important for how a company evolves. For instance, when they started up the 3D model project (3D video scanner) together with Weiss AG, there was a huge technological risk connected with the project. In accordance with this risk, APIteq initially believed it to be just a 50 % chance of reaching a commercial product. However, this number has now changed to a 95 % belief that what they are doing will be a success.

APIteq's products are highly specialised and developed in conjunction with their very research oriented partner Weiss AG. While APIteq's products might just recombine existing technology, specialised competence has been required for the development of these products. This creates a gap down to any competitors wishing to do the same, and it also narrows the scope of APIteq's technological field.

The management of APIteq is very sales and marketing oriented. So, from the very start, when considering the development of a new product, they speak with their customers, get their opinions during the process of making a new product, and transform their commentaries into ideas. An example of how they may get an initial idea was given by a spokesperson for APIteq:

"The initial idea might start in quite an arbitrary way. Someone might be noticing what we do on land, and then they might say 'Wow, can you do this subsea?' and then we start to wonder if it's possible. However, most of our impulses probably come from ourselves and from thinking forward, and what may be possible to achieve."

The process APIteq goes through when developing a product may be illustrated by a review of how the company worked to create the VAM software. The developing phase of VAM started back in 2010 when APIteq first decided to focus on the oil industry. They also realised they would have to be more updated regarding technology developments in the market. Every second year the world's largest Photo conference is arranged in Köln. APIteq was on the lookout for a camera system that could replace the more commercially available one that they were using. APIteq did some pre-research to figure out which company was the best, and after having examined a lot of companies, APIteq decided to collaborate with Weiss AG in Germany. APIteq bought the camera system from Weiss AG, and immediately started using and testing it. They discovered that this system also opened up the possibility for 3D measurements; this was an internal type of software Weiss AG had developed with this purpose in mind. Together the two companies discovered there to be a lot, software wise, they could do to offer a significantly better product. During the next 8 to 10 months in 2011, they started a joint technology project, where Weiss AG had the responsibility of carrying out the project, and APIteq's part was to help define what this software should do. As the project progressed to the point where they could start to use the product, 15 months of testing and feedback followed. In a way APIteq is the bridge between the oil customers and the developer. The financial aspects of the VAM project were split roughly 50-50 between the two companies. A firm representative described the VAM software to have become *"the bread and butter"* for them.

With their VAM software APIteq will be able to compete in an established industry that uses laser scanners to make 3D models. The hope is that what they deliver will significantly improve efficiency and reduce costs for the customers. The preliminary response from customers has been very positive. The production of the VAM software is a form of market pull.

This was a detailed review of the process that APIteq went through for their most recent development project. The largest hindrance for the company to be even more innovative and engage in development is limited resources. Financial resources pose naturally as the largest challenge. APIteq has done their development without investors or any money in the bank to spend; as such they have managed this on top of the daily operations (selling, conducting jobs etc.). Their only financial aide has been from public subsidies and customers.

Finishing this part-section a quote from a representative of APIteq will be used:
"Having good ideas are great, but making these ideas come to life is rather daring."

4.2.2 Epsis

The technological trajectory of Epsis has its origins from the time (around the millennium shift), when one of the two founders started working with and trying to understand what integrated operations were. So initially, at the time when Epsis was founded, the two founders considered product ideas, which were somewhat different from what the company has today. However, as the company developed, the ideas for their product narrowed and took slightly different directions. This led to the products that Epsis have today. The development was to a large extent done in cooperation with customers. The technology that Epsis delivers is thus the result of a clear market need, i.e. demand-pull. A representative of Epsis described their beginning as:

"We noticed some open fields in the technology landscape that a little business at Kokstad could fill. We were users of the technology, and started developing the technology towards IT, and thus answered a demand from the market."

In the beginning when figuring out their technological trajectory, Epsis collaborated with Chevron and Statoil on a joint industry project. At this time their technology was at an exploratory stage, and the partnerships proved to be a good influence when determining the shape of their technology. After roughly three years, this collaboration culminated in a product that resembles what Epsis delivers today. Following the initial collaboration, Epsis entered into an alliance agreement with Chevron, where Epsis got to develop their technology through the licenses that

Chevron bought. This set the base foundation for developing the company's technological trajectory. It can additionally be mentioned that Epsis owns the patent for their products.

Neither when they began in 2003, nor now, does there really exist similar systems to Epsis' in the market. Their products may be categorised in between what the market refers to as Business Process Modelling (BPM) and Unified Communications (UC). UC is Lync, videoconference, SharePoint and other collaboration solutions/platforms, where information, decisions and business processes are unified. Epsis' product deals with transaction-oriented processes. These types of processes are common in most industries, but what Epsis does, is to use their own product to visualise different decision points and integrating them with existing applications. When the company chose to enter the oil and gas industry it was due to their experience, knowledge and the potential for considerable gain. Epsis aims to be a different solution for an already existing market, and according to the company there is currently no direct competition in the market. However, the company must avoid becoming too special, otherwise customers might lose interest. Should the company become too specialised, this will also mean that their technological trajectory will narrow considerably.

As touched upon in previous sections, Epsis is today primarily concerned with getting sales, not further technological software development. In this manner the technological path of Epsis is undergoing a pause. Though, as with all software products, the company will never be quite done developing and improving its software. How the company now considers itself to be innovative, is through communicating their business proposition to the market in such a manner that the market can understand it, or in the words of Epsis:

"Customers own, in a way, the processes of change in the oil companies and the supplier companies. We are the technological enablers for these sort of changing processes."

When it comes to being innovative Epsis had a strong technological innovation focus about 5-6 years ago, resulting in a relatively generic product. Due to the company's development this focus on innovation and development has changed. The place where

they try to be innovative today is when communicating with their target market. So, when asked about what had been most important for the company during the last three years, they replied that it was the opportunity to work long term with customers. This has let them keep their belief that what they are doing is greater than just these few customers, and by scaling their production they may provide value for many. The companies, which have implemented Epsis' solutions, have ended up modifying their own processes or adjusted them so that they may use Epsis' tools. Epsis has experienced this alteration to give value to their customers. The main achievements for Epsis for the past three years may not be the incremental changes and modifications they have done to their product. The main achievements are rather the process innovation in the customers work processes due to their use of Epsis' products. Epsis described this as:

"The important thing is how one may use the technology, instead of the technology being an asset in itself."

Epsis appears to have temporarily stagnated somewhat in their technological developments and path. This is likely due to the current phase of the company, and subject to change as the company evolves. While developing their software, Epsis has relied upon previous competence, i.e. built upon their knowledge and experience, and they have continued to do so throughout the history of the company. By building upon their technological fundament and accumulated knowledge, the technological trajectory, which Epsis follows, continues to narrow and become more specialised. Their technology thus appears to be path dependent and in a temporarily stasis. Should the company ever decide to change their technological path, it will likely be due to changed requirements from the customers or due to threats to their survival.

Epsis' technology is currently at a satisfactory stage for the company, and the ability to broaden their technological scope lies in expanding their technology to fit other markets. Opening up their technology to other markets will enable them to refrain from becoming too narrowed. Epsis has, in fact, already started catering towards other markets.

4.2.3 Scantrol

When establishing Scantrol, the founders broke with the technological direction of their previous company, Scanmar. This was due to their ideas being unsuitable for the technological trajectory of Scanmar. To develop a competitive product the newly founded company invested heavily in R&D. In the beginning they entered only the marine research and fishery markets, as Scantrol could make use of Scanmar's connections to establish itself in these markets.

Scantrol operates, as previously mentioned, in three markets; the offshore market, the fishing market and the marine research market. For all three markets they deliver similar winch control systems. While they develop their products along one main technological path, Scantrol manages to diversify itself with regard to choosing target markets, and thus keep their technological trajectory more open-ended. A company representative described their situation in the following manner:

"Operating in three markets means that if offshore is quiet, then we focus on the fisheries, and if fisheries are quiet, we focus on offshore. If they are all quiet, we will focus on doing research."

Scantrol considers their main innovation over the last three years to be the AHC system. As AHC is a very important product for the company, they have started to consider this a base-product, which they may improve by enhancing its functionality and by adding supporting functions. The company's success with AHC can be attributed to Scantrol's previous learning and experience from the years in fishery market. It would not have been possible to make the products Scantrol has today if not for the company's increased competence, and understanding of the markets and its technology.

Time schedules for their products may be up to five years. During the development of a product, it is important for Scantrol to actually see that the technology works, and in this manner having an overall control of the financial safety for the company. The company has a strong focus on R&D, but user-

friendliness is also important for Scantrol. It thus follows that while Scantrol is improving and upgrading their products, the company makes efforts to receive feedback from their customers. So, their technological trajectory is not completely driven by research, since they also pay attention to what the customers want, and also to the market in general.

As the company's different products bear similarities to each other, Scantrol's employees may more easily assist on different projects. As Scantrol is a relatively small company, there is room for flexibility and choices in the employees' everyday work. This helps create a dynamic environment and perhaps also to open up the company's prospects.

The company is wishing for a new EU directive concerning environmental requirements in the fishing industry to come through. The EU is becoming more and more focused on quotas and dumping of fish. Having worked on EU projects on previous occasions, Scantrol is now looking for a political motivation for their customers in the fishery market to have the kind of products that Scantrol deliver, specifically Scantrol's Deep Vision system. Currently, internationally and within Europe, the EU is in the process of making funding available for technology related to projects within the fishing industry. This will be a great way for Scantrol to increase their sales and also for receiving financial support to develop projects. As the company relies on governmental influence to expand their markets, the EU acts as an instigator towards governments, companies and the fishing industry to clear the path for new technologies to enter the fishing market. In this way political directives can be enablers for the development of technological paths for small companies. Or in the words of a company representative: *"Hopefully, political influence will give us assistance and support in developing our projects, as well as making it easier to sell our products."*

To continue their progress and improve even further, Scantrol deems it important to invest even more strongly in R&D. With this intention for the future the company aims to employ a few people who may primarily work with development of new technology. Carrying on with R&D will consolidate their technological trajectory, as well as make room for pursuing related technological opportunities.

An example of how Scantrol operates may be drawn from their Deep Vision product in the fishing segment. The industry faces quite a technological challenge during the situation as the trawl is lowered down into the sea. As the trawl gradually goes deeper into the sea, they do not necessarily know when fish starts coming into it, or when to pull the trawl up again. There still might be fish coming in while they are busy pulling the trawl up. Suddenly they have all different kinds of fish, regardless of whether they want it or not, on deck. The problematic issue is they don't really know at what time, at what depth or what type of fish they will be catching. Today they usually use sonars, giving them an idea if there are several layers of fish there. However, the sonar can't tell the exact size or the different species of fish that exist at different depths. Instead, it would be preferable to put Scantrol's Deep Vision system down through these layers to verify what's down there, and then use the sonar afterwards as a measure of control. According to Scantrol there are currently no other commercialized products that can do what their product is capable of.

To optimise their technological development and maximise returns, Scantrol, in a strategic way, makes use of the three markets they serve. An example of how Scantrol might proceed developing a product: First they will develop it internally until they have built a system that may not easily be copied. After this period of development, they may collaborate with the Institute of Marine Research (IMR, Havforskningsinstituttet) to improve and test their technology. IMR usually assists with this because they will be interested in buying Scantrol's technology. In the end Scantrol may take the product to the offshore market, as this is the market with the highest threshold for introducing new technology. So, while Scantrol may serve three different markets, their technological trajectory swerves its way through all three of their markets.

4.2.4 Stormfjord

Stormfjord has been in business since 2007, and is thus the youngest of the four companies analysed in this thesis. Even so, the basic idea behind Stormfjord was born around 1990. In the mind of the founder, the initial idea evolved and developed about 20 years before Stormfjord was founded. Through his

employment the founder discovered a market need. Aided by the founders' profound working experience within the field Stormfjord would develop its technology in, the competence and foundation for starting a company was solid. Even before Stormfjord was founded, Statoil, a large potential customer, showed their interest. Statoil proceeded to give the founder, along with his co-founder, financial incentives for developing the technology that he had been pondering for many years.

In the operational years since funding, the company tossed around with the initial idea, did variations, moved a bit away from the idea, and in the end returned to the initial concept. Stormfjord used these years to mature. In December 2013 the company delivered the first solid version of what they considered to be their main product with standardized and stabilised software. Thus, it seems the company took the time necessary to figure out what technological direction they wished to evolve in. A representative of the company told this in the following way:

"During our short history, we have experimented with lots of different ideas. We have often changed strategies, but always maintained the same basic philosophy, or way of thinking. This philosophy, together with the technology, what we communicate, as well as our communication with our customers has been fundamental during our history. We deliver new products and present other angles, but always grounded on our own solid foundation."

Stormfjord has from the very beginning known which technological direction the company wanted to take. They did use some time to get where they wanted to be, having to figure out the path as they went along. All their actions and decisions have worked as self-reinforcing mechanisms to more strongly build up their core product. The product may thus not have changed greatly since its initial shape, but it bears a clear technological trajectory due to its history and development.

The changes their product has undergone throughout the company's history have consisted of many small incremental ones, and a few larger and more extensive ones. A small team of developers is behind the company's product; it is thus not the founder himself that has developed the product in its entirety. When not quite

satisfied with a software solution, the development team often wishes to start completely at the beginning again. Starting all over makes the software code nicer and the result better, but it also takes considerably more time. A person in the company's management phrased his opinion about this as: *"In the future I will not let the development team decide the course of the firm's direction. I will have to make sure we do not start from scratch every time. Our products will be made through an evolution, and not a revolution."*

There existed similar technologies in the market at the time of founding. Even though others had similar technologies, Stormfjord had then, and still has, components of their technology that cannot be found elsewhere in the market. The two companies that Stormfjord could be compared to, have both been bought for substantial sums by larger companies. There are also some large companies having in-house departments, which do things similarly to what Stormfjord does. As said by a representative at Stormfjord: *"Among the companies delivering the same type of technology as we do, I believe we are the only company left which has not been bought by an industrial group. At the time they were acquired, the others had a larger customer base than we currently do."* It should here be noted that Stormfjord views a possible acquisition as a potential exit strategy in the future.

It is unlikely that the company will try to drastically change its technology within the nearest future, as Stormfjord is currently more concerned with selling its existing products. However, branching out into different industries remains an open option for Stormfjord, and the management has already been in contact with the building and construction industry. Other relevant industrial markets include the military, urban industry, shipping, offshore and other land based industry. Branching out and operating in different market segments will assist in slowing down the narrowing of Stormfjord's technological trajectory. In turn, by making the product viable for several markets, it will become more generalized and applicable in different situation. This holds true, even though the technological needs in the different markets are more or less similar. As a representative at Stormfjord expressed: *"I am at this stage, convinced that we will expand into other industries."*

4.2.5 Comparison of the firms technological trajectories

The technological trajectories of the cases all have a firm foundation from the founders' previous work experience within the oil and gas sector. The founders have typically been introduced to the technology through previous employment or experienced a need in the market before deciding to establish the companies. The theoretical concept behind Stormfjord appears to have the longest history, dating back to when the founder was in his early twenty's and started to work for Statoil. Scantrol is probably the only company, among the four, that may be characterised to initially have been a technological spin-off from a parent company.

Regarding the companies' products and ideas, all four have to some capacity held on to the ideas that they had initially. Their technology has changed as the companies have evolved and found their positions in the market, but neither one of them appears to have undergone drastic technological turnabouts. All four prefer to reinforce, build upon and further develop the technology that they already have. Their technology is thus progressing towards becoming more and more specialised, but with narrow product scopes and few markets this is difficult, and perhaps undesirable, to avoid. Scantrol with its focus on R&D and with marine research as one of its primary markets is perhaps the company with the most open technological trajectory, but even so the company has one trajectory, not one for each of their markets. This is due to the fact that they rely on similar technology for all three of their markets.

Being relatively small entrepreneurial undertakings, the companies have chosen to try and find very small technological niches where they may excel. APIteq is currently in the process of trying to broaden their product scope and enter new markets. The same goes for Epsis and Stormfjord with regard to markets. This shows a willingness and ambition for the companies to possibly have several technological building blocks.

Paying attention to markets, as well as listening to and collaborating with customers, have been parts in shaping the technological trajectories of the companies. Having a nice technological idea is not enough, there also needs to be an interest and demand in the markets for what they seek to deliver.

Table 1 summarises the technology of the firms, and the technologies' placing in the market.

	APIteq	Epsis	Scantrol	Stormfjord
Main product/innovation	360˚ PanoramicGuide / VAM	Integrated systems (process innovation)	Winch control systems	3D visualisation
Primary market segment(s)	Oil and gas	Oil and gas	Marine research, fishing, offshore	Oil and gas
Secondary (potential) market segments	Subsea, Norwegian Correctional Services	Healthcare, public sector, bank & finance, Norwegian Correctional Services	–	Building and construction, military, city industry
Similar technology exist	2005: No Today: Yes	Yes, but less advanced	For some of the firm's products	Yes, though the firm has some unique components
Technology originate from	Marked-pull	Marked-pull	Technology-push (mixed with market-pull)	Market-pull
Type of innovation	Incremental, recombination of existing technology	Incremental, process innovation	Incremental, somewhat radical	Incremental

Table 1 The firms' technology trajectories

4.3 The knowledge of organisations

This section will look at how the companies generate knowledge and how their knowledge may be defined. This part of the analysis thus tackles the companies' focus on R&D, their knowledge bases, creativity and generation of knowledge, and also the collective organisational knowledge of the companies. A broad and diverse knowledge base may indicate a company with an open organisational path.

4.3.1 APIteq

When it comes to the company's knowledgebase, APIteq considers theoretical knowledge to be of relatively small importance. Consequently, practical knowledge is their main skills and knowledge base. This is because they consider practical knowledge to be a prerequisite for dealing with customers in their target segment, but also as a necessity for conducting their daily work and technology development. Another aspect the company considers to be highly underestimated, and vital for their business, is the importance of sales and project management.

Several of APIteq's employees have long experience from the oil and gas sector (their current main market). Classifying the employees' backgrounds as practical engineering experience, the company may be characterised as having a synthetic knowledgebase. They learn by doing, using and interacting, and their main goal is to deliver reliable solutions for their customers. It should also be noted, that APIteq in accordance with the definition of the synthetic knowledge base, prefers to do incremental improvements to their existing technology and products. This is to reduce the risk of having to undertake new enterprises. However, the company still has ambitions to expand their product line, and taking on related, but different projects.

As the company's product is a visualisation and communication tool based on photography and video, APIteq also has employees with a background from design and IT. To be able to keep their market position at the same time as they are developing their products, it has been necessary for APIteq to be creative throughout the company's history. When asked how APIteq work with creativity, a company representative mentioned their *"two o'clock coffee"* and proceeded to explain: *"Creativity works by talking together and solving problems along the way. We have*

no formal processes concerning creativity in APIteq. Our creativity is partly based on projects, but mostly on opportunities."

Subsequently APIteq does not have specific processes for being creative. Continuously working together, discussing relevant issues, whether it may be small problems or larger ones, makes room for creativity as a dynamic process. As APIteq is a small company a lot of the daily work is tied to customer projects, where everyone has to pull their weight. When a business opportunity presents itself they follow it.

These opportunities often appear at trade fairs where the company has had the chance to meet people with different experiences and who work with completely different issues. This acquisition of opportunities may be viewed as a knowledge exchange between people of different cognitive backgrounds.

When looking at the company in this manner it appears to fall under the symbolic knowledge type. One of the characteristics of this knowledge base is that is relies on project work, where the involved parties often make use of external specialised knowledge and resources. APIteq's main partner, on the technology side, is Weiss AG in Germany. Weiss AG works closely with the local university environment and can likely be characterised as having an analytical knowledgebase. Whenever APIteq starts development on a new project or product, the company moves forth only after receiving positive feedback and commitment from customers, as well as from their research partner Weiss AG. This dependence on participation from customers is a safety mechanism to ensure the company's continued survival and success.

APIteq may be said to inhabit a combination of the two knowledge bases: synthetic and symbolic. They inhibit traits of these two knowledge bases, firstly the synthetic type, rooted in engineering experience and with the innovation model of doing, using and interacting. And secondly the symbolic type, rooted in creativity and design, and with an innovation model based on learning by doing. This knowledge mix works well for the company today, as they have managed to bridge together the cognitive distance by merging competencies of designers and that of engineers.

Due to the company's size and resources, APIteq has to prioritise existing projects. To finance their projects, they need to have a constant focus on operations as well as sales and delivery. With this in regard, they consider sales expertise to be an incredibly important asset for the company, or as a representative of the company termed it: *"Without sales we will have no business; it's that simple."* Even with a strong market orientation they try to make time for further development of their products. When it comes to their projects and operations the same people are involved on all levels. This is of course with regard to relevant area of competence.

Collaboration with customers, mixed knowledge bases and a focus directed outward from the company, are all factors indicating a variety in APIteq's knowledge build-up. This diversity helps to broaden the organisational path of APIteq, and it also lays the foundation for the company to continue expanding its technology trajectory.

APIteq does not have any significant connections to the local R&D institutions, and their collaborations partners (excluding Weiss AG) possess the same type of knowledge base, i.e. mainly engineering experience. A representative of the company described what they do as: *"We do not do research, we do development. As such, the most important thing we do is not development, since it is the daily operations that keeps us going."*

4.3.2 Epsis

As of today Epsis is mainly concerned with expanding the market share of their existing products, and thus values sales management and customer relations highly. Going back a few years to when they first started out, Epsis placed a significant amount of resources into understanding each of the various disciplines the oil and gas sector consisted of. The underlying reasoning was the company's quest to produce a solution for implementing new ways of working and collaboration. Their solution was to be an interaction venue between the different disciplines. To reach their goals, the company was required to obtain in-depth knowledge of their customers working environment and processes. At this time many of the employees of Epsis had an experience based knowledge background, giving them an understanding of everything from start to finish. This helped position their product into their customers' value

chain. The first few years in the company's lifetime may then be described as exhibiting a synthetic knowledge base.

As the company matured, what Epsis demanded of its employees was altered. The employees' work is now more directed towards the changing process that Epsis is a part of. Consequently, knowledge within sales and marketing has become vital for the company, and this means that the company has separated the production from the consultative part of the company. Epsis is now more narrowed towards helping their customers implementing their solutions, and with assisting the customers in changing their own processes. Regarding the change of Epsis' alteration of knowledge focus and focus on sales, a representative of the company said: *"Time carries change with it, and our company is undergoing both change and maturation. Or said in other words, we are continuously working according to market adjustments."*

Epsis deems it important for its employees to take joy in their work and in the success of the company. Epsis knows the employees have a feeling of ownership towards the company. They regard this as a sign that they are running a firm where innovation and creativity is appreciated. Being creative at Epsis can be quite untraditional. Their creativity is based on how to determine the best way to use their products to solve problems for their customers. The company describes their look on creativity and how they apply this aspect of their knowledge in the following manner:

"Creativity is often about designing a product or performing a service to fit into the market. Creativity may be a bit different to us. We look at how to use our assets to solve problems for our customers, and perform our adjustments accordingly. Combined with our own way of pitching our product, we enable customers to discover us and realise the value Epsis' products may bring them."

Epsis has developed its software internally, and expects its team to be focused and oriented towards creating the software in an effective manner. Having the software well integrated within the rest of the company is of a great value for Epsis. Considering the product being about integrated operations, Epsis has, throughout the company's history, employed both designers as well as people with more engineering based knowledge and 'know-how'.

Epsis wishes for the knowledge, competence and way of communicating acquired throughout the years, to be codified and easily transferable. Epsis' main product is about integrated operations and also about easing the cognitive distance and communication line between different disciplines. If Epsis can show customers the highly professional competence that Epsis has developed and cultivated during the years, as well as demonstrate the added knowledge generated by using Epsis' products, it may make the company's products more susceptible for the customers. A company representative expressed this as: *"We wish to communicate our method of thinking and working as clearly as possible."*

In overall and throughout its history, Epsis may be classified as a company with a synthetic knowledge base. Even so, the company houses elements of a symbolic knowledge base since their work is oriented towards design. In addition, the founder of the company has a background and experience that would fit with the characteristics of an analytical knowledge base. However, during the company's history, the founder has moved away from the majority of strong ties that previously bound him, and to some degree Epsis, towards R&D institutions. Epsis also put strong value on sales and marketing competence, as their current primary objective is to gain larger market shares.

4.3.3 Scantrol

Scantrol does, as mentioned previously, operate within three different fields (marine research, fishery and offshore market), though for all three markets, winch control systems mainly characterises their projects. There are many similarities between their different markets. The engineers work on projects according to area of expertise, though the products' similarities allow for overlapping work to some extent. The knowledge required for the different projects thus spills over between the different engineers, which in turn results in a constant knowledge exchange. The employees are, in other words, given an opportunity to further build their knowledge.

When asked if Scantrol consists of people with engineering and experience-based knowledge, the company replied: *"Yes, even though we do have a relatively young environment, Scantrol is mostly made up by experienced people who has been*

working here for quite a while. Our recruiting has lately been focused on experienced people, not as previously, when most of our attention was directed towards graduates." However, Scantrol does take on trainees, for example students from TAF (technical and general subjects secondary schools) and also bachelor students. As such they strive to be an including company. By opening the company up to students in this manner, Scantrol may to some extent shape the mind-set and knowledge base of potential young employees.

The company has at any given time employees working with R&D. Scantrol subsequently consider their core expertise to be within research and development (one of their primary markets is marine research). Scantrol is additionally currently seeking to hire more people for their R&D Department. For these types of positions they consider both graduates and experienced people. Scantrol does in addition have competence within design, marketing and customer support. Overall, the company tries to remain a diverse company.

Scantrol does not have a formal framework with regard to innovation and creativity. What they do have is a regular "*Monday meeting*", creating an arena where the employees may discuss issues and ideas. Furthermore, the company's small size enables a flat internal structure and lowers the threshold for bringing up different topics.

Based on Scantrol's heavy focus on R&D, the company may be said to have an analytical knowledge base. This goes hand in hand with Scantrol having their own R&D Department, as well as working closely with other research institutions. The analytical innovation model favours a linear research strategy, and Scantrol may appear to have linear traits in their development. Even so, the company has been having contact with and ties to both customers and other research institutions during their technology development process. The Institute of Marine Research (IMR) is one of Scantrol's main partners, which the company has collaborated with on numerous projects.

Though Scantrol has an analytical knowledge base, many of their employees have a synthetic engineering background. This goes to show that it is not necessarily the

experience of individuals that form a company's knowledge base, but rather the collective effort of all the employees pooled together. It should also be noted that the category of an analytical knowledge base is not a rigid definition of the company's structure and overall knowledge pool. Scantrol may merely be said to tend more strongly towards the analytic than towards other knowledge bases.

Having the knowledge to operate within three different markets and with a substantial focus on R&D, Scantrol has a solid foundation for their competence. This base has enabled the company to keep a broad organisational path, which may enable Scantrol to adapt and change if need be.

4.3.4 Stormfjord

The founder of Stormfjord considers R&D to be very important for the continued success of the company, and so far all the software development has been done internally. Outsourcing of the development has been considered, but not done. The company has, at most, bought a few libraries of programming code that others have developed and maintained. Seeing as the company recently had to downsize its stab from 8 to 4 employees, some development projects have had to be put on hold. Stormfjord is instead focusing on sales and marketing of their core product.

Although the founder has a background in physics from academia and research environments, describing Stormfjord as having an analytical knowledge base may be a bit of a stretch. Their innovation model is more compatible with that of a synthetic knowledgebase where the focus is on doing, using and interacting. That is to say, the company seldom follows a linear development; they have had ups and downs. Stormfjord has from the very start worked closely with customers, and some of the company's tumultuous past has been related to projects, with collaboration partners, being cancelled.

The contact that the company has with the R&D environments is mainly done through taking on students. For the time being there is one student from the University of Oslo and one Ph.D. student from Germany. Stormfjord does in addition usually have at least two master students connected to the company, and also there are currently six bachelor students doing some work for the firm. The students may collaborate with

the company in different ways, but the majority of the work, which the students do at Stormfjord, is in connection with papers for their education.

Up until this point Stormfjord has mainly consisted of programmers with different backgrounds. While one programmer may be more technically oriented, another may be more oriented towards design and creativity. The cognitive distance between the developers internally in the company has so far been relatively small. It will be interesting to see how this cognitive component will evolve following the company's downsizing as well as an increasing focus on sales and marketing.

The founder of the company views creativity as very important. While the company may not have any formal structures surrounding creativity, the founder does on occasion use different creative exercises to jerk the employees out of their daily work routine. The mentality behind this is to get the employees to view what they normally do in a different setting, and consequently increase their innovative and creative potential. Being creative may lead to new knowledge for the company. A representative of the company explained the importance of creativity in the following manner: *"Everyday people sit in front of a computer doing what they are used to do and feel comfortable doing. If someone outside of this closed system comes and shakes up the ingrained notions they have, it may get them into a state where they can see things in a slightly different light."* and *"Being creative requires a surplus of time. Whenever people get bored or relaxed, there is a chance that creativity will emerge."*

Stormfjord considers their core competence to be 3D data, or more accurately 3D CAD Data. It is also important to be able to handle this data in large quantities and to apply it in a favourable way for both Stormfjord and their customer. The company considers the knowledge that they possess to be a collective organisational knowledge, and not just a gathering of individual competencies. A representative from the company termed this knowledge as:

"*Stormfjord has perhaps taken a direction and gained knowledge that is unique because it does not only come from one mind. The knowledge has come collectively from all of us.*"

The company seeks to offer their partners and customers the competence, which they have built up while developing their technology. According to the founder, the premises for the company's technology are based on a philosophy and knowledge about 3D visualisations. The company has immersed this philosophy and knowledge into the programming. A representative from Stormfjord explains: *"We have built our technology on top of a foundation of knowledge, and furthermore, we have built a software on top of our technological concept."* Stormfjord places a high value on the transferral and teaching of knowledge, as well as how the company's partners and customers may use their software. While the source code may be IP protected and their work processes tacit, Stormfjord seeks to provide codified knowledge to customers as well.

Stormfjord does, as mentioned, not fall clearly into the category of either a synthetic or an analytical knowledge base. Moving away from these two categories of knowledge bases, a more appropriate way to characterise Stormfjord's innovation model may then be by a mix of the innovation models of the aforementioned two knowledge bases. This mixed model is termed CCI (complex combined innovation). Note that CCI is an innovation model, and not a knowledge base. The CCI model combines the use of scientific and practical knowledge, and in this mix Stormfjord tends more strongly towards the synthetic category than the analytical one.

4.3.5 Comparison of knowledge

The prevalent factor for all four cases regarding their knowledge bases is that all have elements of a synthetic knowledge base. This corresponds well with the fact that they all operate to some degree within the oil and gas industry. The main portion of the workforce in this industry has an experience based engineering background, and all four companies have at least one employee that has previously worked for a larger oil and gas company. The founders of APIteq, Epsis and Stormfjord do for instance possess this type of background.

All of the four companies are relatively young and small, and as such seldom have a surplus of resources to allocate for basic R&D. All of the companies perceive R&D to be important for their development within technology and knowledge, but prefer to do development on projects only when they receive incentive and support from their

customers. Scantrol distinguished itself in this regard by always having some employees working with R&D, as well as collaborating significantly with R&D institutions in the local environment. Scantrol was also the only one of the case companies, which exhibited strong traits of an analytical knowledge base. It may also be worth mentioning here that the main development partner of APIteq is an R&D company located in Germany.

Due to their products and workforce, APIteq and Epsis may be the two companies that come closest to having elements of a symbolic knowledge base. This is mainly due to the fact that they employ designers, i.e. people with a creative background, in addition to the rest of their workforce. As such, their knowledge base may be a mix of the symbolic and the synthetic one. However, Epsis has in later years swayed their primary focus over to sales and marketing of existing products.

Based on the empiric data, Stormfjord was shown to inhibit the characteristics of a CCI innovation model. This classification could probably have been extended to APIteq and Scantrol as well, but the latter two tend slightly more strongly towards the synthetic and analytical knowledge base, respectably.

Clearly defining a company into the rigid categories of the knowledge bases may not always be expedient. The categories are generalisations, and not a blueprint of the better solution. Why a company ends up with a given knowledge base may be contributed to that company's history, employees, industry and vision.

Both Scantrol and Stormfjord emphasised in their interviews that they have acquired a collective organisational knowledge, which is greater than the sum of the employees' individual knowledge. The companies learn and develop as an organisation, and not just as a gathering of individuals. Though neither APIteq nor Epsis specifically mentioned this, they are both also likely to experience, and also have, a collective organisational knowledge. *Table 2* summarises the different knowledge of the firms.

	APIteq	Epsis	Scantrol	Stormfjord
R&D	Some testing and development	Software development	Yes, and in collaboration with R&D institutions	Most of the software
Have primary R&D partner(s)	Yes	No	Yes	No
Knowledge base	Synthetic	Synthetic	Analytic (with some synthetic elements)	Combination of analytic and synthetic
Collective organisational knowledge	Yes (not explicitly stated by firm)	Yes (not explicitly stated by firm)	Yes	Yes

Table 2 The firms' knowledge

4.4 Routines and organisational structure

This section aims to focus on a couple of other organisational features that may in some way have an impact on an organisation's technology development. This entails the inherent routines and internal organisational structure and of the companies. Organisational routines are very important for how companies operate, i.e. the work processes surrounding technology development. As Nelson and Winter stated "*all regular and predictable behavioural patterns of firms are routine"* (see chapter 2.3). The routines and structure develop as part of an organisation's path and technology.

4.4.1 APIteq

Whenever APIteq starts up a new project there are some common features or routines. Firstly they consider who of their employees possess the required competence, secondly they take into account whether or not to involve their partner Weiss AG, and lastly they look at available funding for projects.

The internal company structure of APIteq is very flat, and this creates an atmosphere for easy communication and flexibility in their routines. The company anticipates that their form of rapid communication may change as the company grows, and expects to experience a greater need for managing the internal structure. Having a flat organisational structure and informal routines may be an indicator for APIteq not experiencing a strong form of path dependence.

An aspect that may differ APIteq from many other organisations is the fact that the overview of all their procedures, documentation, formal rules and regulations only exist online. A representative of APIteq humorously described this situation: *"Our entire procedure overview is Internet based. This is slightly unusual. Others probably still have a sort of holy folder somewhere."*

4.4.2 Epsis

When Epsis was asked about what the company considers to be the most important competence the firm has gained over the years, they listed their knowledge about how oil companies may operate in a more effective manner by improving their processes and also their routines. A representative of Epsis explained this as: *"We have, over time, developed some good routines and an understanding for how to develop the necessary software in an effective manner."* The company could have chosen to outsource their software development, but has refrained from doing so. Epsis has thus been enabled to create an internal development team that is well integrated with the rest of Epsis' way of doing operations.

Epsis uses the same routines for all of their projects, and the development team's routines are continuously improved upon. Having good routines for development, commercialisation and customer relations are a great value for the company. The feedback Epsis has received from customers affirms this value.

The product that Epsis has developed concerns, as mentioned, integrated operations, interaction and collaboration technology. Due to the nature of their technology, the company also tries to make use of their own technology internally. Epsis' software has, with time, become part of the company's routines, and a way of furthering their technology development. These routines may assist Epsis to more effectively develop its path and explore opportunities.

4.4.3 Scantrol

The routines of Scantrol have, according to the company, always been up to par, but their manifestation and nature has changed somewhat over the lifetime of the company. Being a small company (17 employees) with a flat structure, there has

throughout Scantrol's history been little need of documentation and formalised work routines. However as they now have three important markets to serve, Scantrol has started to establish procedures and descriptions as a basic guide to the company's work environment. This need for more and improved documentation is a direct consequence of the company's growth over the years. Previously, a too rigid and formal structure would have been perceived as an inconvenience.

As the company continues to grow, and having a well-developed framework of routines, being able to rely on their routines will become more and more important. Already the company has a set of routines that underlies all their projects. A spokesperson for Scantrol phrased the necessity of good routines as: *"As we continue to grow, we cannot stay dependent upon individuals; it is vital to become dependent on a system."*

Many of the company's international employees experience a flat company structure as unfamiliar; this structure is typical for many Norwegian firms. However, their mix of foreign and Norwegian employees exemplifies the potential benefits and downsides of having a flat structure. Foreigners are often used to a more strongly implemented internal hierarchy. The international employees may thus find it unusual not to be given clear instructions from a boss regarding what to do. This flat structure may make the daily operations more unstructured and make it difficult to monitor individuals and specific tasks. On the other hand it may help create a very creative environment. The view regarding a flat company structure as presented here, is based on the opinion of a person in Scantrol's management. On a more general note, both flat structures and hierarchies can promote and be good environments for technological development.

4.4.4 Stormfjord

The organisational structure of Stormfjord is extremely flat and independent, and the management is more interested in being a facilitator than a boss for the company's employees. As a consequence the internal working routines are loose, the employees may, to an extent, determine how they want to organise their day. This is an organisational structure, which some individuals may flourish under. Others experience too much freedom as difficult, and consequently require less responsibility

and more direct guidance and leadership to be effective. A spokesperson for Stormfjord described this independent mentality as *"freedom with responsibility"*. This liberal working environment was also one of the causes behind the company's downsizing earlier this year.

The company's work structure may on the other hand help foster creativity and further technology development. People given more choices in their work may become more motivated on their chosen projects. Though Stormfjord's working environment appears to be quite independent, that does not mean that the company lacks guidelines and a basic set of routines for their development and customer handling. Further, as Stormfjord's routines develop, the company's path will take on a more predictable and clear form.

4.4.5 Comparison of the routines and organisational structures

By having done similar working processes many times over the years, the routines of the companies have developed and become standard references for how they operate. All four companies thus have (to some degree) routines that they continuously make use of. The routines are inherent to the different firms, and have during the companies histories developed into set frameworks for how they work.

As all of the companies are relatively young and small, they exhibit a trait common in these types of firms; a flat organisational structure. This may change as the companies grow, but for as long as they remain geographically based in Norway, the change in this aspect is likely to not be particularly significant. Stormfjord is definitely the company with the most flat, relaxed and independent structure. The other three have a higher number of employees and are subsequently more structured.

The routines and structure of the companies are very important for how they develop their technology, and also for how their organisational paths may evolve.

Table 3 summarises the routines and organisational structure of the firms. Year of founding and number of employees are also listed as the routines and structure may to some extent be connected to the age and size of the firms.

	APIteq	Epsis	Scantrol	Stormfjord
Year of founding	2005	2003	1988	2007
No. of employees	12	35	17	4
Type of routines	Informal	Somewhat formal	Neither informal nor formal	Very informal
Organisational structure	Flat	Flat	Flat	Very flat

Table 3 The firms' routines and structure

4.5 Networks of the firms

After having considered the companies' history, technology trajectories, knowledge and their routines, this section will examine the companies' networks, and how the companies relate and interact with their environment.

4.5.1 APIteq

Since APIteq collaborates closely with their customers, their network is also largely comprised of their customers. The customers are an important source for feedback and for gaining new impulses. The cognitive distance to customers vary, but it is safe to say that while they may communicate in the same manner, and sometimes have the same culture, APIteq's technological service bridges a gap in the customers tool base.

In terms of professional language, the cognitive distance between APIteq and their customers seems positive, i.e. it brings new impulses to the company. There are a lot of large companies within the oil and gas industry in Norway, and it might be difficult for a small company to introduce new technology to this market. APIteq considers the oil and gas industry to be very conservative in this manner, or in the words of APIteq: *"It seems difficult for an oil company to start a process where they consider using new technology. On the other hand, when they do manage to get started on a different track, they are known to be very good at getting the work done."*

The qualifications needed for being allowed to work within the oil and gas industry are very strict. Highly professional companies, like APIteq, have the necessary safety courses, ISO-certification, experience, and are absolutely capable of meeting the demands from the oil and gas industry. Since the entrance demands are quite a challenge, not many will be able to operate in this market. This is one of the reasons why APIteq has chosen to prioritise their markets as they do. As stated by a company represent: *"99 % of the people who wish to do what we do, are excluded from working with the oil and gas industry, due to the high competence requirements."* A company, which lacks the necessary knowledge and experience, will be excluded from the oil and gas market, as the cognitive distance will be too great to easily overcome.

APIteq's close technological partnership with Weiss AG may be called a bridging network (see chapter 2.5). The two companies have a contract-based relationship regarding technological development, financial transactions, milestones, plans, etc. Though APIteq does not have any close ties to R&D institutions, Weiss AG collaborate closely with university institutions in Germany. For APIteq, this provides an indirect secondary network of very loose ties. Their partnership with Weiss AG is the only one that APIteq deems important. Other connections are mostly regarded as good intentions, which APIteq seldom finds solid enough to be realised into full-scale partnerships.

APIteq does, in addition to Weiss AG, also partner with two other companies: Top Side Offshore Technology in Netherland and Sidus in the U.S. The two companies work with complimentary technology to APIteq. However, APIteq did not place any significant importance to these two companies during the interview.

APIteq is currently working together with an American firm to include real-time information from sensors into their 360° PanoramicGuide. As APIteq does not yet know how interesting this new product will be for the customers, they collaborate with the American firm to test it. Should they be successful, it is likely that the American company will be their first customer for this new addition to their production. When trying to conceptualise this collaboration it may be termed as a mix between a bonding and a bridging network; bonding as the companies operate within

similar fields, and bridging as the companies collaboration may fill complementary technological challenges that they both face. Due to the company's geographical distance, the collaboration may also be deemed a global pipeline.

Before starting the sales process APIteq initiates contact with customers to inform and make the customers aware about their company and products. Being a small company, it is imperative for APIteq to ensure the customers have received all information related to the task. Doing so, will in turn generate a higher sales rate for APIteq. To achieve the best result APIteq mainly makes direct contact, either via phone call or e-mail to set up a meeting, and then meet the customer, or potential partner, face-to-face.

Though APIteq has a solid reference list, the company is still seeking to land a larger customer. They are hoping to get a large one with a lot of platforms and rigs. Getting to install their systems on all of this customer's rigs and platforms will generate a huge order for the company. Additionally, the transaction cost for installing their 360˚ PanoramicGuide again and again with the same customer will be significantly lower than if they were to approach a completely new customer for every instalment, which of course save resources for APIteq.

To expand their network, attract potential investors and showcase themselves, APIteq participates at conferences, e.g. OTC. Operating in a global industry their international network is larger than their local national network, regarding their cooperation with other firms, and also their success in the market. According to APIteq their limited presence in the Norwegian market may be due to a more conservative and reserved attitude in Norway, which is connected to Norwegians tendency to act according to the Law of Jante (In short this "law" states that a person should not think they are anyone special or that they are better than anyone else). In other parts of the world, as in Brazil or in the Middle East, the company is met with a completely different respect and interest than in Norway. Since the company has a lot of global contacts, their employees are expected to do quite a lot of travelling during their work. To better facilitate their international network APIteq has established small offices in Houston and in Rio.

In connection to their new subsea project, the company hopes to be part of a more local collaboration as well, but so far they have had little contact with Norwegian technological companies. APIteq has a membership in NCE Subsea, and they are pleased with the yield this membership has returned. For example, when applying for preliminary funds for their subsea project, they received instead of funds, an engineer with 35 years experience from the subsea industry. APIteq was very happy with this solution. As the company continues to expand their collaboration with local actors in connection with their subsea project, the added benefit from the local buzz may increase.

4.5.2 Epsis

One of the main focal points for Epsis is to communicate to the market their way of operating in such a way that the market understands it. This has been incorporated into what they look for in partners and customers when building their external network.

Since the founding of the company, Epsis has done consulting activity to keep a positive result as they developed their product. This has lowered their threshold for coming into contact with customers and potential partners, as well as increasing in their local buzz. They have all the time kept strong ties to a selected few customers who they have collaborated very closely with. The dialogues with customers, i.e. some oil companies, has let Epsis gain insight into the customers' challenges , giving the company opportunities to develop a better product. This part of the company's network has brought complementary knowledge, reinforced and expanded upon Epsis' ideas, and all together been an important source for improving their products. As such, these close customer relations represent the company's bonding and bridging networks.

To exemplify the company's bridging network, an alliance agreement with Chevron, a large American oil company, may be mentioned. Initially, Chevron made contact with Epsis through previous acquaintances. The partnership the two companies entered into in 2006 was a technology alliance. Or as a spokesperson for Epsis put it: *"The challenge with all innovations is to generate interesting technology, as well as there being a market for this technology."* As such Epsis' partnership with Chevron has

served more as a global pipeline that they could spar technological ideas with. Even though the collaboration between the two companies did not lead to new innovations, their partnership was very useful in giving user-requirements for the technology that Epsis developed. In fact, their alliance led to a worldwide licensing agreement with Chevron in 2009.

Since Epsis had a technology alliance as well as customers across the Atlantic, it lead the company to opening up offices in Houston in 2008. Being geographically close to their customers, without a 7-hour time difference, enabled them to get continuously feedback from their network in the States. To be able to increase their customer base in the U.S., and having a network and acquaintances on several continents, have been extremely important for Epsis.

When asked about whether they mainly cater to the international or to the local national market, Epsis replied that they have been doing most of their work internationally. Among their customers are big international oil companies, with their list of references including: Chevron, ENI, FMC Technologies, Frank Mohn, Halliburton, Kriminalomsorgen Vest, Petrolia and Total. The two companies that they have worked most closely with during many years are Chevron and Hydro (before it became StatoilHydro). Epsis may be a small company located on the outskirts of Bergen, but its attitude towards doing business is global. The company has also established offices in Stavanger, Norway, in Houston and in Aberdeen, Scotland. This enables the company to maintain and expand their global network, and also lower their transaction costs.

The company has three other partners that are worth mentioning. These are: Nordialog – a strategic partner which enables the customers of Epsis' TeamBox to acquire additional audio visual equipment and services in Norway; then there is CCOMM – the UK reseller of Epsis TeamBox, which they have collaborated with to provide solutions and support for customers; and lastly there is Arch Group – an Australian company within the oil and gas industry located in Perth, and they represent Epsis within Australia, New Zealand and Southwest Asia. (Epsis 2014) These three companies are important parts of Epsis' international network, and help maintain the company's global pipelines.

On the local level in Norway, Epsis has received valuable support from various public programs. Among these are SkatteFUNN and IFU (industrial research and development contracts) via Innovation Norway. In the beginning they also had support from the Research Council of Norway through a PhD program with the University of Bergen and a consultancy firm. Another actor in their network is NCE Subsea, a local network that has come to be globally connected. NCE Subsea has helped place Epsis in a position where they may meet other companies dealing with the same kind of challenges. The local buzz that NCE Subsea help create, facilitate the formation of bonding and/or bridging networks amongst the member companies. Meeting customers and gaining attention around their product has also been a benefit of the NCE Subsea membership. A concrete example of Epsis' connection to NCE Subsea is the following: *"We were invited to participate in a film that NCE made. They placed the film on their webpages. In doing so, gave us a wider network as well as more attention around our brand."*

Though the founder of Epsis has a profound background from academia, the company has no formal projects in collaborations with the local R&D institutions. Even so, since the founder of the company has been involved in the university's environment for many years, it makes the founder, and by extension the company, able to sustain the relationship with the university. Though Epsis does not utilise these relationships, they may be accessed as a peripheral information network.

The methods or channels that Epsis use to reach and initiate contact with their external network vary greatly. They participate on conferences and local networks, and also use their network to uphold direct relations and meetings with their customers. When it comes to this last point, a very important aspect for the company is to meet the customer on their home turf, so to say. This enables Epsis to get closer to their customers and maintain strong ties.

4.5.3 Scantrol

Scantrol has with three markets to serve a wide range of distributors, suppliers and partners all over the world. It is an extensive network with many different types of connections and relations. The company has a wide range of distributors in Africa (1),

America (2), Europe (5), Asia (3), and in Oceania (1) (the numbers in brackets refer to how many companies they partner with in the different areas). Similarly, the company has a wide range of winch manufacturers in Africa (1), America (3) and in Europe (5). (Scantrol 2014) Some of these partners only serve one of Scantrol's markets, while others serve several. How does a small company like Scantrol manage to acquire such an international network? In the beginning the company used the distributor network of their parent company, Scanmar, to build their network. This has serviced as a great entrance portal and lowered the transaction costs when entering the markets.

A partner Scantrol has worked with for many years is IMR (Institute of Marine Research). This partnership has allowed Scantrol to reduce costs when testing their systems, give input and assist with technology development, and also to help marketing the company to their network. IMR is as many R&D institutions largely turned towards cooperation with the international community. The strong collaboration Scantrol has with IMR may be referred to as a bonding network in the sense that the two companies operate to some extent within the same fields. However, what the two companies do for each other is to fill technology, knowledge or resource gaps, and as such, a more correct term for their collaboration may be a bridging network. Due to Scantrol serving the marine research market, the cognitive distance between Scantrol and IMR appears to be just right for them to get the most out of their partnership.

The partners that Scantrol works together with are a mix of research institutions and commercial partners. Some of them are the Research Council of Norway (NFR), CRISP (Center for Research-based Innovation in Sustainable fish capture and Processing technology), IMR, Egersund Trål and Simrad. If NFR is steering a project, they may agree to put in the same amount of funding as the commercial partners invest in resources. This ensures that all the involved parties contribute, and it also facilitates further R&D within marine research.

The industries that Scantrol operate in are quite global, and the company believes that this has been a factor in enabling them to easier establish themselves internationally. Or as a spokesperson for the company uttered: *"With our focus on keeping an*

international presence in our niche, we try to attend as many tradeshows as possible in different parts of the world. We have been concentrating a lot of our attention towards Asia, as well as Houston and Aberdeen, U.K." Working in worldwide industries ensures the possibility of the company getting a constant stream of new impulses through their global pipelines.

Another advantage that the company has discovered while working with their international network, is the fact that significant portions of their employees are international. One employee speaks Spanish, which is very convenient dealing with partners or customers in Spain or Spanish-speaking countries. Working in the company is also an engineer from Beijing, which is great when directing their attention towards Asia or countries with significant cultural differences from Norway. Having an internal international community in combinations with an external international network, lowers the apparent cognitive distance as well as the transaction costs, which in turn eases the threshold for collaboration.

Moving back to the local buzzing network in Bergen and Scantrol's connection with it, the company has had only limited contact with NCE Subsea in Bergen, even though the company operates in the subsea/offshore market. Scantrol has collaborated somewhat with the R&D institutions in the region. They also have some subcontractors in Bergen, like Bakers, Oneco, Bekas, A2G (the design company that made the DeepVision prototype), and some subsea consultants. All in all the company is working closely with the local industry, and also tries to use subcontractors from the local industry. As such, establishing strong relations to their partners and subcontractors is important to Scantrol, and a representative for the company explained it in the following way: *"It is much better to be an important customer with one or two subcontractors, than to be just a small customer for a large international company."* It is also easier to connect with other companies and establish strong partnerships while being are geographically close.

Though the company operates on a global basis for all their three markets, it is perhaps the marine research and fishery markets that are the most globally connected ones for Scantrol. This is in particular quite common for R&D industries. Their offshore segment consists of 80% exports. This market does also have a more

concentrated customer base that Scantrol tend to meet in Singapore for instance. To sustain their large network the company makes sure to follow up and maintain their relations.

A list of some of Scantrol's major clients include Kongsberg Evotec, Protea, ABAS Lifting, PGS, Vard Electro, Ibercisa, Ace Winches, JJ Offshore, Fugro Subsea Technology, Maritime Developments, Rapp US, SMD, Oil States and Helix Wellops.

4.5.4 Stormfjord

Stormfjord spent their first four years in the incubator Nyskapningsparken, where they got to be part of an environment with many companies that faced the same challenges at them. While other companies they met there might not be relevant industry partners, they could still be an important part of the company's network as to bringing impulses, motivation, culture and in general contribute to the social and local buzz.

When it comes to Stormfjord's current network in and around Bergen, they have regular meetings with different companies, but this has insofar not resulted in any partnerships. Following the reduction of their workforce, Stormfjord has become more open-minded towards acquiring partners and resellers. The company even considers it likely to enter into a partnership project with somebody in Bergen that can deliver their solutions. A representative of Stormfjord said: *"A part of our strategy is to grow through partnerships with other companies."*

The company has so far been a member of NCE subsea, but is currently considering whether or not they will continue this membership. This is due to the company having to shut down their subsea department in Stavanger, as their subsea projects were deficit. Even so, it should be noted that the company considered their NCE subsea membership as useful. NCE Subsea provided them with some network and also incorporated them into the local buzz.

Stormfjord's founder moved in 2013 to Spain with the hope of establishing the company internationally. With time they will expand their markets, but currently their main market and network reside in Norway. The way the company first initiates

contact with their network, potential partners or customers was either through references, phone calls, conferences or through other acquaintances. Stormfjord has for example been chosen by the Research Council of Norway to have a stand at the Norwegian Innovation Park this year. This is a great way of expanding their network as well as partaking in the local community.

The founder of Stormfjord has, as previously mentioned, a background from the University in physics, but even so, the company has very little network towards the local R&D institutions. They regularly use students to do work for them, and as such, market themselves towards potential future employees, as well as building tenuous bonding networks towards individuals.

In the company's reference list some of the following clients and collaborating partners may be mentioned: AkerSolutions, Bergen University College, HP, Deepocean, EMAS AMC, Lundin, Theano, Subsea Design, Reach Subsea, Vilvite, Nvidia, ABB and Statoil (Stormfjord 2014). Among these, HP and Nvidia has provided Stormfjord with equipment for testing, and as such worked as a bridging partner. Nvidia, being located in the US, serves as one of the few global pipelines for the company.

The two most important partners for Stormfjord have probably been Statoil and Lundin. The latter has served as a technological bonding partner for the company, and Statoil has been a main customer and collaboration partner since the company's beginning. This is due to the founder having long working experience from Statoil, and Statoil has progressed to become a main supporter of what Stormfjord has developed.

4.5.5 Comparison of networks for the firms

When comparing the networks of the four companies, three of them (APIteq, Epsis and Scantrol) consider their international network, i.e. partners and customers, to be of primary importance. While all of them work in global industries, Stormfjord, as the youngest and smallest company, has yet to affirm a strong international presence. The companies' international relations represent a variety of global pipelines, technological alliances, and also of bonding and bridging networks.

The companies choose their partners for convenient or strategic reasons. APIteq's partnership with Weiss AG was for instance a strategic bridge to further develop their technology, and the same goes for Scantrol's collaboration with IMR. When choosing their partners all of the companies seek to establish long-term collaborative relationships, as recurring work with the same partners will lower transaction costs.

Regarding the companies' interaction with the local industry; among the four, Stormfjord places the most importance on local collaboration. Most of the companies have received grants from the Research Council of Norway, but Stormfjord is the only company to have been fostered in an incubator (Nyskapningsparken). All four companies have membership in NCE Subsea, and have through this membership been exposed to the local industry buzz and thus gained additional network.

Having a substantial network has been a key component for the companies to be able to develop their technology. The different networks of the companies have provided them with feedback, equipment, knowledge, new impulses, customers, partners and other resources. The firms' networks are summarised in *table 4*.

	APIteq	Epsis	Scantrol	Stormfjord
Location of offices/personnel	Bergen, Houston, Rio	Bergen, Stavanger, Houston, Aberdeen	Bergen	Bergen, Spain
Geographical scope of significant network	International	International, local	International national, local	National, local
Significant partnerships	Weiss AG	Chevron, Hydro (formerly)	IMR	Statoil, Lundin
Connection to R&D institutions	No	No, though founder has previous network	Yes	Takes on students, founder has previous network
Have bridging networks	Yes, Weiss AG	Yes, Chevron	Yes	Yes, Statoil, Nvidia, HP
Have bonding networks	No strong ones	Yes	Yes	Yes, Lundin
Participation in local buzz	Limited	Yes	Yes	Yes
Significant global pipelines	Yes, many	Yes	Yes, many	No

Table 4 The firms' networks

4.6 Organisational path dependency

This section chapter will look at how the companies' organisational path dependence has evolved, and also how this has affected their technological trajectories. The main concern here is thus to look at organisational path dependence by elaborating on firms' knowledge, routines, network and technology trajectories.

The concept of organisational path dependence may, as mentioned in the theory section, appear somewhat vague and difficult to measure. In section 2.2 Sydow, Schreyögg et al. (2009) gave a very broad definition of what organisational path dependence includes, which is: "*all kinds of imprinting effects of the past on*

organisational behaviour". When analysing the companies this statement needs to be made measurable in some manner. The parameters used for describing organisational path dependence for the cases will look at how the firms have changed over time, that is, how the technology trajectories (i.e. many technologies or very specialised technology?), routines, knowledge base and network of the firms have developed.

Path dependency is very closely tied to the history of the firms, and time is consequently an important aspect in this regard. With time, firms typically go through three phases: preformation, formation and lock-in (as described in section 2.2). Path dependence is thus a description of the evolution for a specific track over time. Characteristics of this development may be labelled as path extension, path renewal and path creation. I will consider why some of the firms may experience path extension, renewal or creation, consider what may be reasonable choices for the firms, and I will lastly consider how other factors, as for instance industrial conditions, may affect the firms current and future paths.

4.6.1 APIteq

When APIteq discovered their market opportunity in 2005, they did something, according to themselves, anybody could have done, they created a company and started to sell. The technology and solutions that APIteq use (the camera system and software), were insofar already available in the market in 2005. The existing technologies had just not been applied in the manner that APIteq envisioned. As such their 360° Panoramic Guide was not a radical technological innovation; it was the combination of existing technologies for a new purpose. They discovered a business opportunity and created the market for it, or in the words of a company representative: *"It seems we are pioneers within a very little niche in the oil industry, and more or less, we have created this niche ourselves."*

The preformation phase for APIteq was the period before funding, when the founders got to know the technology, which they would later build a company upon. In this period the knowledge they acquired and the decisions they made lay the foundation for creating a company. The second phase, the formation phase, began at founding in 2005, when APIteq catered to the hotel and boats industries. During the preformation phase and the formation phase APIteq starts to develop its organisational path

dependency, and how the company was formed has shaped the evolution of its technological trajectory.

Holding on to their technology of 360° photography and visualisation technique, the company moved from the hotel and yacht industries to the oil and gas industry in 2009. They thereby kept their line of technology and merely changed their market. Changing their segment market was a strategic choice: the oil and gas sector is a lucrative industry worldwide, and in addition, APIteq already had competence within this field. In this way the company drew on past experience and knowledge to help shape the future direction of the company. Changing the company's organisational path in this manner would not have been possible without the synthetic, engineering based knowledge that several of APIteq's employees possess. As a representative of APIteq stated regarding the oil and gas industry:

" We found the threshold to go working with the oil industry quite high. For companies it's a big step to do offshore, what has previously only been done on land. With our unique competence there was a unique possibility to work within the oil sector. This is why we chose to change our market. Other companies will find it very difficult to compete with us, unless they are already operating in the oil industry."

When APIteq decided to change their market segment to the oil and gas industry, they used roughly 9 months to develop the product for the oil market. The company also used this period to decide whether or not they should let go of their existing customers and direct their full focus towards the oil industry. This change of market in 2010 represented the second stage of the formation phase. Though APIteq has possibilities to expand into other markets, the company has by now firmly attached themselves to one technological trajectory.

Some of the company's history and past choices may, according to the management, have been arbitrary. Though when looking at the company's past in hindsight, there appears to have been a line of self-reinforcing mechanisms that have placed APIteq in its current position. These self-reinforcing mechanisms have their roots in the routines and organisational structure the company has developed throughout the years. The organisational path dependence of APIteq has thus been moulded together by

informal routines and a flat work environment. APIteq is conscious to focus on building upon what it has already created: its technology, knowledge, routines and network. All of this ensures that the company is evolving in a desired direction.

APIteq is further concerned with staying ahead in their little technological niche. The company has so far not experienced large amounts of direct competition, mainly due to the fact that their technological field is very small and specialised. This will likely change as the market matures. As such, APIteq continually tries to stay ahead by attending sales exhibitions, collaboration with customers and partners, and participation in innovation programs, e.g. ACCEL Subsea First Step 2013. By trying to be proactive and keeping ahead in their discipline, APIteq may currently reside in a weak positive lock-in.

The company does at present experience success for their products in the market. They anticipate that the market will change, particularly internationally, during the coming years. So, for the future APIteq hopes that their 3D scanner (currently in development) will acquire a significant market share. This is due to the company entering an established market with this product, and that their 3D scanner will be notably better than existing models. In addition, there is the company's subsea project that is just starting up, and may prove to be a success. If they receive positive responses to the end-results of these projects, they will have significantly broadened the technological trajectory of their existing main product, the 360˚ Panoramic Guide. Having several products in the market can extend the company's present and future possibilities.

Part of APIteq's ability to achieve success and extend their product portfolio lies in the diversity of the company's knowledge base. By combining creative designers with engineers from the oil and gas industry, and with a strong research partner in Weiss AG, the company has over time bridged different knowledge bases. The collective organisational knowledge of APIteq has thus affected how the company has been able to develop its technology, and also characterised the shape of the products APIteq deliver to customers at present.

The company places great value on keeping close dialogues and partnerships with their customers. This is to ensure survival and profitability of their projects. APIteq has so far with their 360° PanoramicGuide completed about 37 projects. References in their customer base includes Statoil, Saudi Aramco, Zadco, BP, Petrobras, GDF SUEZ, Dolphin Drilling, Transocean, Shell, Seadrill and Talisman Energy. This is a substantial reference list with many large international companies. APIteq's network has greatly helped the company advance its technology, and at the same time kept the company's organisational and technological opportunities more open-ended.

Regarding how APIteq is experiencing organisational path dependency, the firm has evolved gradually by building new bricks on an existing base fundament consisting of technology, knowledge, routines and network. The company is still developing their path, and while they have broadened their product scope and opened themselves up for commercialisation in other markets, their core technological fundament is still very specialised. This specialisation may lead to their path becoming progressively narrower, and thus increasing their path dependency.

Path dependency may be viewed as a continuous spectrum, and a company seldom lands on the outer edges of this line. This goes for APIteq as well, since the company is not experiencing a particularly strong form of path dependence. The past experiences and actions of the company, has landed APIteq in a currently favourable position, and it is unlikely that the company in the near future will enter into a negative lock-in. This is because APIteq pays attention to possible opportunities and changes in the market, and as such avoid narrowing their path too much.

The interview with APIteq clearly indicated the company's interest in refining the technology it already has. Continuing to do improvements on their main product, the 360˚ PanoramicGuide, implies that APIteq is characterised by path extension, which is a strong form of path dependency. A sole focus on path extension will eventually lead to stagnation and lock-in. However, APIteq is currently bringing out a new product, the VAM software, which is developed within an adjacent trajectory to their main product. The firm is also, in the process of initiating a subsea project, which will renew APIteq's technological trajectory even more. The introduction of these projects characterises APIteq as a firm undergoing path renewal. The company's decision to

invest itself in path renewal originates from a desire to exploit possible niche opportunities where APIteq might find an edge, and thus broaden its technological fundament. The choice was also due to the firm's partners and network showing a clear interest to collaborate in bringing these projects to life.

Choosing path renewal is a high risk, but the potential gain of a new market success may outweigh this risk. With a strong R&D partner in Weiss AG, well-established routines and a stable main product, the decision to expand the firm's technological trajectory appears to have been a good choice.

The company's products and undergoing project is based on APIteq, together with its partners, being able to recombine existing technology to create something new. Upon getting recognition for the VAM software and completion of the subsea project, I would expect the company to spend some time consolidating and extending the paths of these products before undertaking further path renewal.

To enter the oil and gas industry there is a high threshold. APIteq's management considers their experience from and knowledge of this industry to be a prime reason for why the firm extended its organisational path to enclose the oil and gas market. Now, APIteq also has plans to extend its products into other markets.

4.6.2 Epsis

Going back to the time when the founder of Epsis got his education in petroleum technology, he was at the initial beginning of his career path. When the founder around (year 2000) started working in Roxar, the preformation phase for the company kicked off as the founder became familiar with the concepts that would lead two men to the task of creating Epsis. Though the founder had a background from academia, he all the same paid strong attention to the market. People with a background from academia are not usually known to do so, but due to his foresight, Epsis made sure to develop in a direction that was very well received by their customers. On a side note, the founder considered his academic knowledge background to be a stepping-stone so as to more easily see the longer perspective with regards to markets and technology. Following this, one might say that he was better equipped to see a possible gap between what is technically possible and what may be a potential market success.

In the beginning Epsis started out by doing consulting activity while busy developing their technology. This is a common way for young software companies to generate revenue, and as such Epsis had the necessary financial means to develop the company's organisational path and technological trajectory. The decision to work with integrated operations was not random as the founder reached this decision after having been introduced to the concept through previous employment. This can thus be termed as having discovered a market opportunity. During the first 3 to 4 years the company alternated between investing and capitalising, popularised termed '*the valley of death*' (as stated by a representative of the company), before achieving a steady success rate. From the very beginning Epsis has been affected by the background, experience and knowledge of the founder. The company's organisational path has reached the point where they are focusing less on being innovative. They are moving from having a small market share, to seeking to prioritise taking larger market shares. In this situation it is crucial that they understand their position in the market.

As Epsis collaborates with the same customers for longer periods of time, the company continually receives input from leading companies within the oil and gas sector. This led to Epsis acquiring positive revenue. The influence from their network and commercial actors firmly assisted in pushing the company towards one path, and with world leading customers such as BG Group, Chevron, Halliburton, FMC Technologies and Eni in their reference base, Epsis may be certain that what the company is doing is relevant for all their potential customers. Epsis strives to deliver projects that may be valuable and appreciated in the market. Collaboration with, and feedback from customers is essential for the company to move forward. Their customers have in this manner helped shape the organisational path dependence and technological trajectory of Epsis. This process may be characterised as the formation phase for the company. A representative of Epsis stated the following:

"From the beginning, we have been working together with our customers. From our customers, we have retrieved inspiration as well as research questions. Since many of our customers are leading within the oil and gas sector, we consequently get to know that what we are doing is important to all of our customers."

Having a stable product line and having moved away from prioritising heavily on further development, the main goal of Epsis today is to expand and to obtain a larger market share. To do this the company will need to employ more people within sales and marketing, in addition to more resources directed towards implementation. Though Epsis' technological trajectory has currently stagnated, the company expects, with time, to invest further in the development of their products. In addition, Epsis does make continuously smaller incremental improvements to their software, so as to always keep their technology up to date. Another aspect, which is important in this regard, is the fact that Epsis has incorporated the use of its own products internally in the company. This sharpens their routines, and also makes for easier monitoring of the development and relevance of their products.

A typical day for one in the management at Epsis is described as: *"I use a lot of my time in meetings with customers, on following up sales and consultancy activity, as well as relations with the board. I also work directly with customers to ensure that I keep up to date concerning what we actually use our products for."*

While the company is starting to reach its current goals regarding the technology, the other dimensions of the organisation are still evolving. Epsis is, as mentioned, in the process of expanding their sales forces, and by doing so, they envision marketing themselves deeper within the oil and gas vertical, as well as wider within other verticals like the healthcare sector, the public sector and the Norwegian Correctional Services. Based on the company's development and evolution so far, Epsis can be said to experience a somewhat strong form of path dependency. Their current technological stasis is temporarily placing a lid on their technological evolution. However, this does not mean their organisational path will stop developing. As the company is very aware of their customers' interests, the path dependency that they experience may be considered to be of a less strong degree. This is due to the company's willingness to turn around and do things differently should it be required of them. The composition of Epsis' flat structure, well-established routines, synthetic knowledge base and extensive network should enable the company to be flexible if needed.

Five or six years ago, technology development was the main focal point for Epsis. At the time the company primarily employed engineers and programmers. During the development phase the firm worked to make a generic product, which Epsis today incrementally improves and maintains. Shifting their focus from technology innovation to sales and marketing has placed Epsis' technology en route to path extension.

With no intention of technological path renewal, Epsis is likely to continue its path dependency and path extension until otherwise coerced. In addition to smaller technological improvements, Epsis is also extending its path by expanding into other markets. Due to the purpose of the company's product, integrating operations, Epsis' decision to direct their attention towards market capture and extension, appears to be favourable for the company. Operations within the oil and gas industry have high costs, and many firms in this industry are experiencing a need to become more effective. Thus, Epsis' potential market segment is large, and it is currently not necessary for the firm to spend resources on technology development; path dependency and positive lock-in suits the company's interests.

Epsis has solid industrial knowledge, well-established routines and keeps continually an open dialog with its customers. Retaining this foundation, should the company's prospects alter, Epsis is likely to discover the potential risk in time to adjust itself. However, I expect the need for integrated operations to increase in the coming years, and bar any unforeseen and completely radical competitors, Epsis appears safe from negative lock-in.

Epsis has taken a pause from focusing on technology development, but remains innovative in its efforts to implore its customers to undergo process innovations by using Epsis' product.

4.6.3 Scantrol

The founder of Scantrol broke with the developed path of the parent company, Scanmar, when deciding to make winch control systems for fishing vessels. The period just before and after founding, was the company's preformation phase. Creating a spin-off, provided the opportunity to change both the organisational

structure and the technological trajectory. During the first few years of Scantrol's history, the company worked closely together with the parent company, and since Scanmar had a very high market focus, Scantrol followed their lead in this regard and made use of Scanmar's global network to quickly enter the market. As of today the companies are two completely separate entities, and their collaboration is greatly diminished, but Scanmar did greatly influence the early organisational path development of Scantrol.

When developing their technological trajectory by introducing a new product, for example AHC (Active Heave Compensation), Scantrol typically identifies a potential within a niche market. The company then pours a lot of resources into the development of that product. They will, in an ideal situation, not have any competitors. Finding hidden market niches can be a profitable way of doing business. Scantrol has thus had a large influence on how they wish to shape and develop that market segment. So, while Scantrol works to find their spot in the market, they are also concerned with technology development.

Scantrol relies on their customer base and network to gain information regarding possible competitors, and how the company ought to continue its path. The company brings this information to their development team, and the team starts working to figure out how to meet any potential market threats and challenges. Scantrol has an analytical knowledge base, and consequently a solid focus on R&D. This has characterised how the company's technological trajectory has evolved. The knowledge foundation has also enabled Scantrol to bring specialised products to highly developed markets. Without the concentration on R&D, Scantrol's organisational path would likely have been narrower, and the degree of path dependency higher.

The offshore sector has grown a lot in the last few years, and it is likely this trend will continue. The company estimates the fishing market will remain stable for a while. Scantrol further considers the seismic market to have reached its peak now, and so the seismic market may be starting to recline. With this diversified market portfolio Scantrol appears to not experience a particularly strong form of path dependence. The company is path dependent in the fact that it since the very

beginning continues to build upon and develop their systems and products. Even so, the company's focus on R&D, collaboration with research institutions and on keeping an open dialogue with customers, Scantrol has managed to develop and keep a rather broad technological and organisational funnel. In keeping such a diverse market, the company manages to avoid a too narrow technological trajectory, which might have been the natural development should Scantrol have targeted only one market.

With three international markets to serve, Scantrol certainly has enough to do, but intend to continue growing. The reasoning behind why Scantrol first decided to extend its organisational path by branching out into the offshore market in 2006, was because the fishery market was very quiet at that time, i.e. there was not a lot of orders coming in for fishery products. This meant the company had time to spend developing the offshore products and look at other markets with a potential for orders. This act was a clear sign of the company's formation and maturation. As they were improving and developing the offshore market, the fishery market started recovering very quickly again. Scantrol thus ended up operating quite diversified, and this has kept their path formation more open-ended. All three markets are currently quite stable and strong.

There are many other companies delivering in-house produced cranes or winches with control systems. The advantage for Scantrol is the fact that they are independent, i.e. they may deliver control systems to whomever they want to. To counter for the company not being alone in the market, Scantrol tries to probe the market so that it might find customers that will result in repeat orders. A well-developed set of routines ensures the continued progress development of Scantrol's organisational path and success.

Currently it is important for the company to consolidate what they have done these last few years, in terms of selling new products in new markets (i.e. offshore products). To strengthen their position Scantrol has also hired several additional employees. Based on this and according to the company's history, Scantrol appears to experience path dependency. However, due to their diversity, the path dependence is relatively moderate, nor have they yet reached a state of lock-in.

Even so, they bear some resemblance to being in a weak positive look-in. The company is set in their current path, and as they evolve further their self-reinforcing mechanisms and thus path dependency will become stronger. A spokesperson for Scantrol said the following regarding the company continuing their current three market lines and about branching out into even more markets: *"We've certainly got enough to do right now. Even so, the plan is to keep on growing."*

While keeping to one main technological trajectory of winch control systems, Scantrol has several times throughout its history undergone path renewal. At an early point, the company has accomplished this by having a substantial network and customer base, an internal R&D department and products in different markets. Scantrol has experienced success with continuous path renewal; the decisions to expand have to some degree been driven by necessity, exploitation of opportunities or technological possibilities.

Since Scantrol, while still a small company, delivers products to three markets, the current focus of the firm is directed towards path extension. After having broadened its technology portfolio and number of active markets, the firms is wisely consolidating what it has done. The fishery segment is stable and the offshore segment is growing. Extending and improving upon its current product lines, tending to their customers and keeping a continuous pressure on development, means Scantrol will persist to experience path extension, intertwined with periods of path renewal. In keeping to its current organisational path it is implausible for Scantrol to enter a strong lock-in.

4.6.4 Stormfjord

When deciding to build the company, the founders had through previous work experience, discovered an exciting problem in the market. There was no grand market survey, just a technological challenge which they started exploring and do research on. The two founders of the company brought with them a combined mix of the analytical and synthetic knowledge base. This aspect has helped characterise the company's technology and organisational path development.

The preformation phase for Stormfjord is made up of: The initial stage when the company lacked a clear concept of how it wished to develop, and the years when the founder mulled over the basic idea and discovered a market need. The market, i.e. Statoil along with a few others, showed interest in the young company and supported the company's start-up, and thus assisted in forming the initial organisational path for Stormfjord.

The first few years were rough for Stormfjord with regards to its technology development and its organisational formation. After only eight months the financial crisis hit, and a lot of their collaboration projects with Statoil were shut down. At a time when Stormfjord was supposed to shape the company in their preferred direction, it ended up having some turbulent years with a steep learning curve for its employees. In the oil and gas industry, companies typically have a 20-year horizon for projects, and this posed a challenge for Stormfjord in its first few years. The company was perceived to lack credibility and trustworthiness. Stormfjord is celebrating their seven-year anniversary this year, and are finally starting to notice that the market is regarding them differently. The company is now invited to participate in a number of different technology projects that it was excluded from in 2007. Maturing as a company and establishing an active collaborative and supportive network in a market, which had become more receptive towards their products as the years have passed, has allowed Stormfjord's technological trajectory to take shape.

Currently, Stormfjord's main market is in Norway, and one of its main goals is to expand and improve its sales rate. The company has worked closely together with customers throughout the majority of its history. A large section of their customer base is acquired through acquaintances in the founder and employees' network. Stormfjord has for example recently hired a native English speaker as their salesperson, as the company wishes to start targeting the international market. Should Stormfjord manage to expand and firmly establish itself internationally, it will enable the company to gather its impulses more globally, and this will in turn have the potential to open up their organisational path.

Stormfjord considers entering other industries like the building and construction

industry, the military, urban industry, shipping, offshore and other land based industry. Branching out into other markets will keep the company's path from becoming increasingly more narrow and specialised. The technological trajectory of Stormfjord is thus highly dependent on how other parts of the company's organisational path evolve.

As an organisation Stormfjord is still developing and forming its path. The company recently had to cut their staff in half, and they are now down from eight to four employees. With this halving of the staff, Stormfjord had to close down their office for subsea development in Stavanger. The reason for downsizing was a too loosely organised work environment and too informal routines in connection with negative results for the company's subsea project. Stormfjord has thus shown itself capable of making difficult decisions for the perceived best of the company.

Their primary market is, as mentioned, the oil and gas industry and this is partly due to the founders previously technological experience and connections. It is also, in part, because Stormfjord views this market as having the potential to generate large returns for a small company, and also because this market has the ability to follow through and get projects done. However, it was a difficult market for Stormfjord to enter, which has probably affected the company's choice to invest heavily in a core technology, and proceed by extending its functionality. A stable and lucrative market will allow the company to focus on developing and establishing its routines and structure. This may in turn lead to a strengthening of the company's path dependence and technological trajectory, and also act as a guard against future rough times.

To better understand the company's scope, it should be mentioned that they have launched new or improved products in the market every year. They currently have 3-4 products ready to be launched, and one in progress. Seeing as the company has fewer employees now than before, they are holding off on starting up new projects. Stormfjord is hoping to better fill its order book, and also to extend today's ordering time from 3 or 4 weeks up to two months. Managing to do this will increase the company's predictable revenue. This means it will be possible for Stormfjord to start hiring again, and also free resources to continue developing its technology further.

As the company grows and are able to increase its available resources, its technological and organisational paths will likely become more rigid. Still, Stormfjord is definitely experiencing considerable path dependence as the company strongly prioritizes building upon what they have already done, and by doing so solidifying their path.

Stormfjord, has since founding, been trying to organise its organisational path and develop its technology. The small firm has experienced several ups and downs. Stormfjord tried its hand at path renewal by setting up a subsea department in Stavanger in 2011, but recently had to shut it down. The main focus for the company now is path extension.

The firm has throughout its lifetime been concerned with building upon and improving its initial technological concept. Stormfjord has thus repeatedly increased its path dependency and path extension. Following the recent downsizing of the company, I expect the company to continue in this fashion until Stormfjord has achieved a steady sales rate and a larger market share.

The management at Stormfjord is aware of the importance of technology development, and as such, the company may at a later stage try for path renewal again. However, I currently consider it most likely for Stormfjord to carry on along its existing path, and eventually end in a lock-in. Even so, the firm is still young and flexible enough for its path to change.

4.6.5 Comparison of path dependence for the firms

The organisational paths of the firms are strongly shaped by historic events and acts. In the companies' infancies, all four took the time to figure out and shape how their company was to develop. This has been crucible between the companies' preformation phase and their formation. The preformation phase for all four companies started prior to their founding, and for some (Stormfjord and to a slight extent APIteq) the formation phase is still transpiring.

All of the companies, some more than others, experience path dependency, but none of them can be said to have progressed to the strongest form: a complete lock-in. This aspect may in part be attributed to the companies focus on keeping an extensive network, and in collaborating closely with customers. APIteq, Epsis and Scantrol all have an established international presence, and are thus ensured the acquisition of external impulses and information. Stormfjord is in the process of filling up its order book, and with the ambition to be able to start conquering the international market as well. Scantrol, being able to rely on its parent company's network connections in the beginning, was placed in a unique position, which allowed the company a relatively quick entrance to the international market. A steady sales and export rate has enabled Scantrol, a small company, to have an internal R&D department.

All four firms are very concerned with advancing through building upon and improving their current technology and knowledge base. Like the oil and gas industry they operate in, all four have elements of a synthetic knowledge base. With time, the companies' knowledge and technology will likely become more specialised and move towards positive or negative lock-in. Their organisational path dependency will be further strengthened by a need for more formal routines as the companies grow.

How the organisational paths of the companies have evolved has largely been dependent on the internal and external forces affecting the firms. Operating and succeeding in a large international industry like the oil and gas market, requires small firms to be very attentive to customers and receptive towards new ideas. To be able to assert themselves in this industry, their technological trajectory has to be specialised, their knowledge needs to be equally well put together and their routines efficient. This makes the firms path dependent and enables them to be innovative.

The organisational paths of the firms have altered between path extension and path renewal. All four are concerned with improving their existing products and extending their paths. However, only APIteq and Scantrol appear to have successfully undergone path renewal. Should the need arise; it is likely the two other firms will also attempt path renewal.

Table 5 looks at the path dependency of the firms. To characterise the path dependence the firms' experience, I have sorted them as having a i) low, ii) moderate or iii) strong degree of path dependence. Similarly, lock-in is divided into i) no lock-in, ii) positive and iii) negative lock-in. I have lastly listed the path status of the firms as i) path extension, ii) renewal and iii) path creation.

	APIteq	Epsis	Scantrol	Stormfjord
Degree of path dependency	Moderate	Strong	Moderate	Strong
Lock-in	Weak positive	Positive	Weak positive	Positive
Path status	Extension, renewal	Extension	Extension, previously renewal	Extension

Table 5 The firms' path dependency

5. Conclusion

In the concluding chapter of my thesis I will go through the main findings of the analysis, and set them up against the research questions. I will further discuss how my findings may add to the theory debate concerning technology development, organisational path dependence and the evolutionary perspective. I will then move on to present the recommendations and policy implications of my study. Lastly, limitations of the thesis will be mentioned, and I will also open up for areas of further study.

5.1. Main findings

I will in the first section of the conclusion go through the main findings from the analysis, and consider them in conjunction with the research questions. I will start with the main question:

> *What are the characteristics of technology development in small firms operating in the oil and gas industry?*

To accomplish being successful, innovative and doing technology development within the oil and gas industry, a firm needs to have a certain set of characteristics in

place. These characteristics vary from firm to firm. Based on my analysis, there are a few factors recurring for relatively young and small firms within this industry: previous experience with the industry, elements of a synthetic knowledge base, well-established routines, specialised technology, cooperation with customers and preferably an extensive network as well.

How then may the technology development in small firms operating within the oil and gas industry be characterised? Technology development is dependent on a multitude of aspects, and I have in my thesis discussed: knowledge, routines, networks and how it all may be connected through organisational path dependence and technological trajectories. This point of view places technology development in an evolutionary perspective, where the firms are the innovators.

To better understand how firms evolve and operate to develop technology, I will consider the sub-research question:

What role does path dependency play in technology development?

The entrepreneurs of the different firms have all been centrepieces for the initial path development. The experience, knowledge and connections the founders where in possession of, were crucial for the early path formation of the companies. The firms used what available resources they had to begin building the technology they envisioned. In the cases of APIteq, Epsis and Stormfjord the ideas behind the companies' technologies stem clearly from discovered market needs. The founders of Epsis and Stormfjord experienced, on their own, the problem in the market, before deciding to build a company. Scantrol is also aware of potential market needs, but do, to a larger degree than the other three, push their ideas and technology into the markets.

The evolution and paths of the firms are not linear. They have in their formation taken time to alter, redesign and chose their organisational path. Also, the background of the founders prior to the companies' formation are very important for how the firms have developed, and in particular with regard to what technological trajectory the firms chose. The firms do in general produce incremental innovations, though the firms

may consider their products to be more radical. The firms do in particular categorize new projects and products that differ from what they previously done to be radical.

The organisational paths of the firms have formed as a response to observed opportunities, to strategic and risky decisions and to the experience and knowledge base of the founders. As the firms' organisational paths have been formed, their knowledge bases have been shaped to fit the firms' goals. This includes mixing different kinds of knowledge, as well as bridging competence gaps enabling firms to develop further. The firms have also developed routines and organisational structures for their work processes. While the routines are still quite informal, they have become a significant factor for how the firms develop technology. The firms' interaction with their networks has been the key to the firms keeping their organisational paths open, and avoid winding up in a negative lock-in.

Organisational paths are all in all complex structures, reliant on many variables. The technological trajectories of the firms developed due to the firms' path dependence. Firms' choices, or necessity, to undergo path renewal is mainly a consequence of a firm seeing a possible lucrative market opportunity, or a firm needing to gain a broader technological fundament. Firms' needing to secure their market position and products, or which has recently undergone path renewal, tend to focus on path extension. Based on the findings in my analysis it appears that firms experiencing continuously success, and perceived as innovative, are constantly alternating between phases of path extension and path renewal. These firms have well-established routines, a solid knowledge base and clear goals. Being constantly innovative can be resource draining, and in some periods it is therefore advisable to focus on solidifying a firm's position. Here I will also mention, that I consider all four of the firms, contributing to my analysis to be innovative. Their organisational path dependencies are at different stages, but all of them are interested in keeping their paths open for a changing market. They intend to carry on with technology development whenever needed or when presented with opportunities.

Based on the analysis, I have now discussed the organisational paths of the firms, and made inferences regarding organisational path dependency of firms. I will continue the elaboration regarding how firms develop technology by considering the last of my

research questions:

> *What are the similarities and differences of technology development in the selected firms?*

Looking at the different firms, there is a significant amount of common features, and many of the similarities cover the entire lifetime of the firms. The first noteworthy factor is perhaps the fact that the founders of all four companies have through previous experience, employment and to some degree education, been introduced to the technology they decided to develop. Furthermore, the founders have, when creating the companies, relied on the network they brought with them to get their technologies out into the markets. The early years of the firms' histories were to some degree marked by turbulence. Gaining a footing may be quite difficult for a small company in a large engineering based industry. To counter a potential slow start and obtain funds for technology development the firms did consultancy activity on the side. Even so, the firms managed, early on, to get the first versions of their products out into the market. Neither APIteq nor Scantrol started out in the oil and gas industry. However, due to the potential for large returns, they expanded to this market segment after some years. All four companies do today have the offshore industry as one of their primary markets.

When it comes to the knowledge bases of the firms, all exhibit elements of having a synthetic knowledge base. Operating in the engineering based oil and gas industry the firms have employees with experience from, and knowledge of the market they operate in. However, two companies (APIteq and Epsis) showed signs of having some symbolic elements, which is due to the employment of designers. Scantrol distinguished itself by appearing to be the only one of the four firms to primarily have an analytical knowledge base. The firms seemed to handle bridging different knowledge bases well, and kept their focus on adding to the knowledge they already possessed.

By building upon, and by recombining existing knowledge, the firms were able to develop technology, perceived as innovative, in the market. Whenever practical, the firms sought to do technology development in-house. There were points of

differences between the firms. Scantrol has a small internal R&D department, and Epsis and Stormfjord have done the majority of their technology development in-house, while APIteq has largely collaborated with their R&D partner in Germany. However, all four companies stressed the importance of developing technology in collaboration with their customers (Scantrol stressed this to a lesser degree than the others).

To organise their technology development, the firms have established routines and organisational structure. The common factors here are flat organisational structures for all the firms, leading to an interactive and dynamic internal work environment. Regarding the firms routines, Stormfjord separated itself from the other companies by having particularly informal routines and a very flat structure. Having at least a basic set of routines are vital for a firm to effectively develop technology.

To be able to make the most of a firm's knowledge, technology and routines, the firms are highly dependent on their networks for obtaining fresh input, exchanging ideas, getting in touch with the markets and for developing their technology in desired directions. The four selected firms are aware of this aspect, and constantly seek contact with customers and potential partners. The firms have to various degrees established themselves internationally, though APIteq and Scantrol have been most successful in this aspect. Epsis and Stormfjord have in return benefited from the local buzz. Scantrol does however appear to be well established both on a local and on a global level.

All of the firms do continuous incremental improvement to their technology. This ensures that their technology becomes more specialised and unique in the market, while at the same time extending the firms technology trajectories. The technologies, developed by the companies, do always originate from market needs. Scantrol, with its focus on R&D is the exception here. Scantrol has also most actively pursued several markets at the same time. The other, younger firms, are however in the process of extending their products to other markets as well.

All in all the characteristics of technology development are multifaceted. Firms often operate in similar fashions to each other as their organisational paths develop. Firms

do perhaps not need to constantly develop technology and renew themselves, as there exist periods when focusing on other aspects of a company may be more important. Technology development is more than just R&D; knowledge, routines, networks and organisational path dependence are also part of it. Developing these aspects to the best of a firm's ability improves the firm's capacity to be innovative, and produce new technology.

5.2 Adding to the theory debate

Being a comparative case study, the collected data material is too narrow to be used for an empiric generalisation; however, it may be used to further illuminate the theoretical aspects surrounding technology development and path dependency. Particularly, theory regarding path dependency may appear vaguely defined (Martin and Sunley 2006, Sydow, Schreyögg et al. 2009). With a better-defined theoretical framework, measuring path dependency might be made easier, so that further studies may have a more operationalized concept to work with.

The way I have contributed to this discussion is by giving content to the concept of path dependence by operationalizing the concept through connecting it with the different aspects (technology trajectory, knowledge, routines and network) of an organisation. Evolutionary theory is often concerned with describing events (Martin 2010). However, I have attempted to discuss, and not just describe, why the selected firms have undergone their specific development. Even the concept of path extension, path renewal and path creation have in the past primarily been used in a descriptive manner. By achieving to understand why, and how, a firm develops along an organisational path, and the impact this has on the firm's technology trajectory, I have begun to explain the development of firms and technology. An empiric study, like my thesis, may be at the basis for building up an analytical framework explaining the evolutionary perspective.

5.3. Recommendations and policy implication

This part of the conclusion will be a recommendation towards how the selected firms ought to proceed with, or improve, their innovation practice. On a general basis, I will also infer for my recommendation to be applicable for similar small to medium sized firms.

To help broaden their organisational paths the companies can either expand into other markets or start delivering several different products. APIteq, Epsis and Stormfjord are all in the process of doing so, or have plans to do so within the next few years. Scantrol is here in the position of already having three primary markets to serve, and the firm consequently also has a relatively broad product portfolio. Epsis is currently not interested in broadening its product scope, and is focusing the primary force of its attention towards achieving larger market shares. Pending the success of its current projects, APIteq's product portfolio may be broader in the coming years. Lastly, Stormfjord, having undergone a turbulent time, is now seeking to solidify their company and market.

To remain innovative, I think, a firm has to continuously undergo interchanging phases of path renewal and path extension. However, in order to stay innovative in the case of severe negative lock-in, the firm will be required to undergo path breaking. Trying to be constantly innovative may, with time, exhaust a firm's resources, as research and development are expensive. All of the selected firms are to some degree experiencing path extension, and it is perhaps this organisational path that is most natural to maintain and carry on with. Continuing to build upon existing knowledge and technology is convenient, and may also assist a firm in becoming more unique in the market. The most cost efficient way to be innovative and develop technology may then be through recombining known technology.

Alternating between phases of path extension and path renewal may be a very profitable way for firms to remain innovative. I would recommend firms comparable to those I have analysed, small to medium sized firms, to follow similar organisational paths. Developing technology at regular intervals may stimulate and enhance firms' market position and innovativeness in the long run. Comparing firms to each other may enable firms to become aware of aspects within themselves, which may give incentives for continued development.

5.4. Limitations and further research

The empiric material is subjective to the respondents' opinions and perception, which may, or may not; make aspects of the dataset appear more favourable. I aspired to

keep a critical eye open while dissecting the empiric material, and my impression was that the respondents generally had a realistic point of view regarding their own companies.

However, since the thesis samples a subjective perspective at a given point in time, there exist a time constraint. Seeing as the research questions concern the development and characteristics of developing technology over time, having empiric material from the firms at different stages throughout their histories would have been preferable. This was to a small degree countered as I was given access to previous interviews with three of the firms. A solution here could be to redo the study a couple of times over a period of ten to twenty years, as this would provide deeper insight into the firms' mode of operation and their path dependency. A longer and more profound study may enable further generalisation of the characteristics behind technology development over time.

My approach of characterising technology development and operationalize organisational path dependence has been to understand how organisations operate to develop technology. An alternative approach would have been to place a stronger focus on the entrepreneur and innovation management. Doing so, can add another dimension to how technology development is executed and also add to the analytical framework of the evolutionary perspective.

Aspects, which may be open for further exploration, are how firms connect and mix different types of knowledge. There might be other underlying factors making an impact on how firms innovate and develop technology. To devise a more extensive and general analytical framework of the evolutionary perspective for understanding the dynamics of technology development, further studies should be conducted. Additional studies concerning technology development and organisational path dependence may assist in validating my findings.

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Appendix: Interview guide

Opening question
Could you tell me a bit about yourself? *Your position in the company, how long have you worked here, education and experience (with previous companies).*

Background information
Name of company:
Address:
Industry:
Year of founding:
No of employees:
Management:
Staff:
In Norway:
Internationally:
What is their background and experience?
Why have you chosen to employ them?
What is the core competence (level/subject)?

Could you tell me in short about what your company does? *Technology? History?*

- From where did the original idea originate? *Source of innovation? Previous work, customer, competition, R&D, how was the company founded? Time to first customer?*
- Why did you decide to start the company? *(No. of founders?) Market need? Discover a problem/opportunity? R&D idea?*
- Did technologies similar to yours exist in the market at that time? *Now?*

Competence, knowledge and learning
- I would like to know more about what type of knowledge the company have and use. We differ between theoretical, academic knowledge and experience-, engineering based knowledge, and lastly creative knowledge (designer etc.)
- What type of knowledge do you consider to be the most important for the company? *(key competence)*
    - What sort of knowledge do you employ?
- How may competence and knowledge in the company be transferred to others? *Easily/difficult? (tacit or not)*

Innovation (technology)
- Describe your company's most important innovation/product for the last 3 years? And generally within the company's history?
- In what way do you consider your company to be creative? Where do you get impulses from?
- Currently, how many different (development) projects are you involved in?

- What type of development does your company do? Small, step-vice changes, or development of completely new products which are new for the market *(radical=new in market, or incremental=new for company)*
- Improvements to existing products? *Small or large?*
    - (during the last three years)
- How often do your introduce new products to the market?
- Since founding, has your main products changed? *Small/large changes?*
- How do you work with innovation and development?
- To be more innovative; are there any hindrances for your company?
- Has the industry/market changed in any way as a response to your products/services?
- Do you see other uses/possibilities for your product? *(e.g. in other industries)*
- How do you consider the risk/chances associated with being innovative?

Idea development, knowledge and creativity

- How do you work to be creative?
- What are the key skills your company has developed?
    - Strengths
    - Weaknesses
- From where does the company gather impulses? *(Marked pull, technology push)*
    - *Are your current projects the result of requests from customers?*
- Does the company facilitate for idea development and creative processes? How? *(time for own projects)*
- How does the company generate new ideas? *Brainstorming? Regular activity or as a response to customer demands?*
- What type of knowledge do you usually combine to conduct projects?
- Does your company have sufficient means to achieve goals of R&D/knowledge? Financial, other?

Research and development

- Please tell how development occurs in the company? *(in-house R&D, cooperation)*
- Do you have ties to any R&D institutions (e.g. universities)?
- How important do you consider R&D to be? *(For your company's continued success) Why?*
- How do you prioritise resources for development (R&D)? *Ad hoc character or…? (targeted priority, don't generally do R&D, according to different projects, proactive?)*

Structure of company

- How is a typical workday for you? *(work in project based teams? Specialist roles? Regular procedures, standards and similar?*
- Does your employees do interdisciplinary work?
    - How does your different internal units collaborate?
- When taking on a new project, how/what is your approach?
    - Follow similar procedures to last time? Different? How do you choose team?
    - What sort of knowledge do you combine on projects?

- How is your current company structure? Work environment?
- Has it changed since founding?
    - Due to any technology changes
    - Formalisation
    - Expansion
    - Any changes in leadership
- How is the company culture characterized? Social environment?
- How do you communicate within the company? *Direct contact, email, meetings, other*
- Has introduction of new technology/products changed the way your organisation operates? The internal structure of your organisation? Short term? Long term?
- Do you have any self-reinforcing mechanisms? (technology/organisation path)

Partnerships and network

- In what manner does your company partner/collaborate with other companies during the innovation process? *What do you share? Type of knowledge?*
    - What type of relation do you have with them? /What is their part in the company's innovation work? *Close ties? Loosely? Open/closed collaboration*
    - How often are you in contact, how do you make contact? *Personal, email, phone, etc.*
    - Why you collaborate with them? *What do they bring that you don't have? What are your partners' primary technology/industry?*
    - How are your partners located geographically? And of what importance is this? *Region, (inter)national*
    - Are the partners also your suppliers/customers?
- Does you company seek other similar or different partners?
- How do you work with innovation in relation to nearby companies?

Cluster, geographical connection

- Is your company part of any public or private support systems (NCE? *(i.e. Nyskapningsparken, NCE, ACCEL, Arena,,(other)*
    - Why are you a part of this? NCE subsea
    - What impact/importance has this had for you? What benefits have you acquired by being part of NCE? *Financial, competence, network*
- How is the region and its environment of use (beneficial) to your company? *Importance of industry proximity. Cluster advantages. Geographic location.*
- How would you consider the company's position internationally?

Production, market and management

- What do you consider to be most important to maintain an innovative company?
    - Any specific aspect of technology management you deem important?
    - *Do you have any previous experience with start-ups? If yes, could you elaborate?*
- How do you consider the market situation? *Stable/changing?*
    - How do you view the current/future market competition?
- How do you consider the future possibilities for your company?

    - *Technology? Innovative capacity? Finance?*
- Who do you perceive as market leaders in your niche?
    - *Why?*
    - *Compared to your company?*
    - *Where and how do you seek to place yourself in the market?*
    - *How do you plan to get there?*

Competence and recruitment

- What kind of strategies does your company have for recruitment?
- What type of expertise do you employ? *(i.e. background of employees; academic, engineer, IT, creative design, other)*
- What are your employees' educations? Bachelor, master, PhD, other
    - What are your managements' educations?
- How do you view the availability of relevant resources/people? From what sectors in society to do you envision needing people from? *(for future expansion of the company)*

Extra

- How would you describe the innovative process of your company?
- Before we finish, is there anything else you would like to add?